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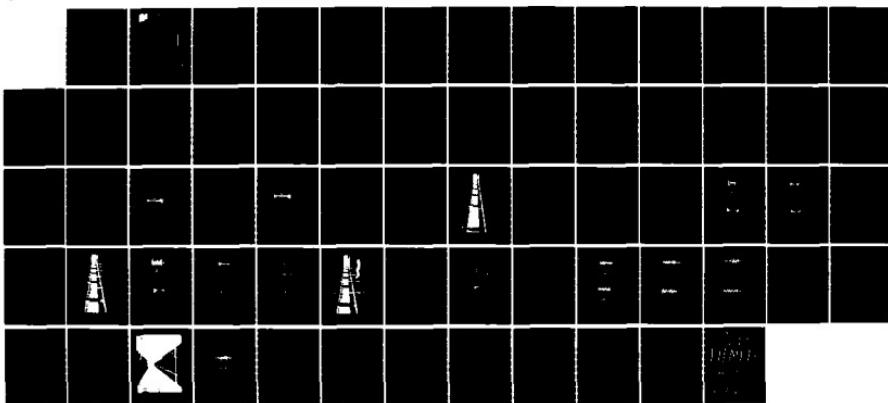
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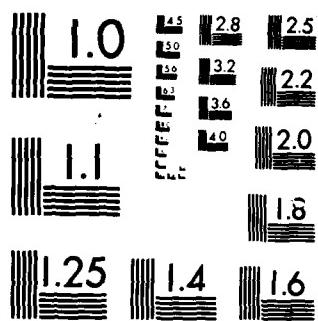
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MICROCOPY RESOLUTION TEST CHART  
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**E-SYSTEMS**

Melpar Division



AD-A165 239

SCIENTIFIC AND TECHNICAL REPORT,  
FINAL TECHNICAL REPORT, TYPE III  
RADIO FREQUENCY MOTION SENSOR  
CABLE STUDIES

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SCIENTIFIC AND TECHNICAL REPORT,  
FINAL TECHNICAL REPORT, TYPE III  
RADIO FREQUENCY MOTION SENSOR  
CABLE STUDIES

Contract No. DAAK70-80-C-0225

CDRL Sequence B001

31 July, 1985

Submitted to:  
Belvoir Research & Development Center  
STRBE

Submitted by:  
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three). The RFMS is an advanced sensor component of the Army's Facility Intrusion Detection System (FIDS). A search for confined field transducers to augment or be used in place of the spatial antennas of the RFMS yielded three candidates: Two types of radiax cable and common 300 ohm twin lead. Each cable was tested to determine the relative sensitivity and the shape of detection field. The 300 ohm twin lead with appropriate impedance matching gave the best overall performance. The results of the cable study are presented in this report.

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RADIO FREQUENCY MOTION SENSOR  
CONFINED FIELD TRANSDUCER STUDY REPORT

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RADIO FREQUENCY MOTION SENSOR  
CONFINED FIELD TRANSDUCER STUDY REPORT

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## 1.0 EXECUTIVE SUMMARY

A search for confined field transducers to augment or be used in place of the spatial antennas of the US Army RFMS yielded three candidates: Two types of radiax cable and common 300 ohm twin lead. Each cable was tested to determine the relative sensitivity and the shape of detection field. The 300 ohm twin lead with appropriate impedance matching gave the best overall performance. The results of the cable study are presented in this report.

## 2.0 INTRODUCTION

An extensive search of commercial catalogs was conducted to identify possible candidate cable types for confined field transducers at 915 MHz. Radiating characteristics, physical characteristics (weight, construction, etc.), and cost parameters were used to select the candidates. As a result of this search, three types of cable were examined in this study. The first two were radiax cables of different manufacture, while the third was ordinary commercial 300 ohm twin lead. The hookup of the cables into the RFMS system is illustrated in Figure 2-1. As shown, a single cable could be connected between transmitter output and receiver input, or two cables could be used: one to transmit, the other to receive. The latter connection was used extensively with twin lead. The purpose of the adjustable air line in Figure 2-1A is to vary the phase of the RF input with respect to the L.O. signal. By careful adjustment of the air line, the D.C. output of the mixer in the receiver slice can be adjusted to zero. This is important because the first stage of amplification directly following the mixer output is direct coupled at approximately 39dB, and for a certain amount of RF input, it is possible that the D.C. level out of the mixer could bias the output of the first stage of the analog processor to plus or minus saturation. When this condition occurs, all doppler signal to the following stages is cut off. This condition does not

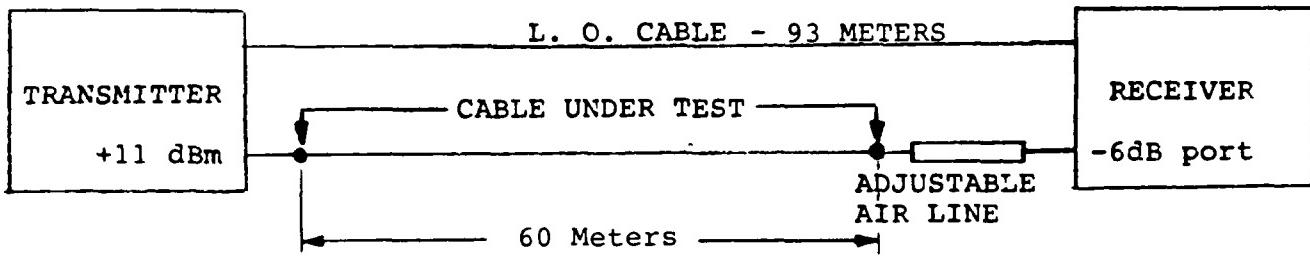


Figure 2-1A

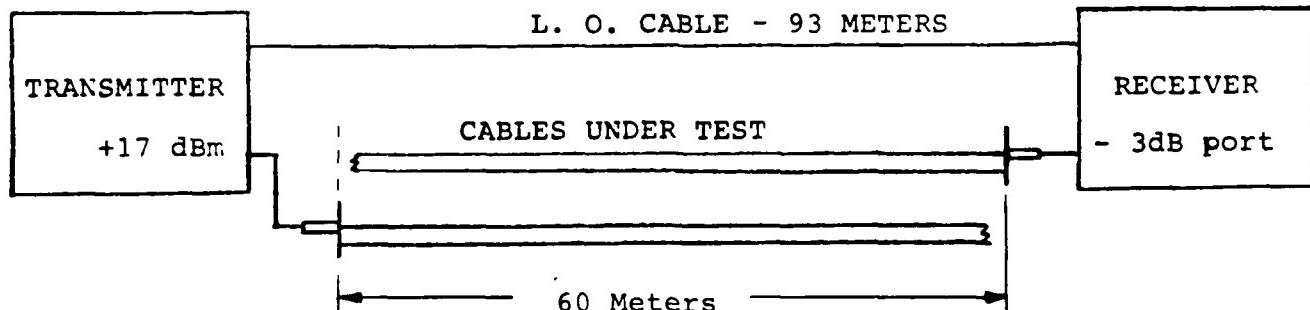


Figure 2-1B

normally occur when the RFMS spatial antennas are used due to the large coupling loss between them. However, when a transmitter output is directly connected to a receiver input by way of a coaxial cable, it is possible for the magnitude and phase of the RF signal at the receiver to meet or exceed the conditions required for saturating the first stage output. This problem can be eliminated in two ways. One way is to decrease the magnitude of the RF signal such that the D.C. output of the mixer will never exceed a safe level. By experiment, it was found that an RF signal  $\leq$  -11dBm at the -3dB receiver port, or  $\leq$  -8dBm at the -6dB port, or  $\leq$  -5dBm at the -9dB port will satisfy the above requirement. However, this method has the effect of decreasing the overall system sensitivity. The other method of avoiding saturation is to vary the phase of the two signals until zero volts D.C. is obtained from the mixer output. Using the phase shift method, the maximum amount of RF power that can be applied to the -3dB receiver port is 0dBm, or +3dBm at the -6dB port, or +6dBm at the -9dB port. This is seen to be an 11dB increase in sensitivity over the attenuation method. The practical method of zeroing the mixer is to monitor the output of the analog processor first stage between pin 6, U1 and chassis ground. A common 20,000 ohm/volt meter or better is sufficient and after zeroing, the meter should be disconnected from the first stage output.

Cables connected as shown in Figure 2-1B (separate receive and transmit cables) do not have the saturation problem mentioned above. This is the recommended connection and is used for the tests of twin lead antennas.

Because of the saturation problem, direct cable connections between transmitter and receiver, where cable loss is less than 25 dB, should be avoided or an air line (or other suitable phase shift) should be used.

### 3.0 ANDREW RX4-3 RADIAx CABLES

The first cable tested was Andrew RX4-3 radiax cable. The approximate length of the cable was 194 feet. The attenuation of this cable to 915 MHz RF energy was measured and found to be .036dB per foot. After hookup, the system gain was set such that detection of motion outside the test area would be unlikely to occur. This was checked by walking in all corridors and rooms adjacent to test area. On the analog processor, this corresponded to a gain switch setting of 4. Preliminary walk tests on the Andrew cable at this gain setting showed poor sensitivity to motion. Throughout the entire length of the cable, one was required to step up to within 1 to 6 inches of the cable before the system could be made to alarm. Figure 3-1 is a strip chart recording of such a test. The upper half of the chart shows a recording of the bandpass output of the analog processor (J5), while the lower half is a trace of the integrator output response (J3). A line marked ".35 volts" is included to show the level required of the integrator output before a detection will occur. For these and all succeeding cable tests, the RFMS Digital Processor alarm filter is set to output an alarm for one detection within a 30 second time window. With these settings, the RFMS alarms whenever the trace is above the .35 volt threshold. The traces were obtained by approaching the cable from 10 feet away, walking about 1 ft/sec, and stopping when the system alarmed. After holding still for about 10 seconds, the test was concluded by stepping back away from the cable. The initial alarm would not occur unless one was within 6 inches of the cable. The upper trace of Figure 3-1 shows no sign of doppler, but only a disturbance in the field immediately surrounding cable. This type of disturbance is not caused by the speed of the intruder, but only by his presence within the near field of the cable. The trace indicates only a D.C. level shift out of the RF mixer. It might be thought that increasing the processor gain would remedy the above condition. However, in this configuration the RFMS oscillator noise does not allow full

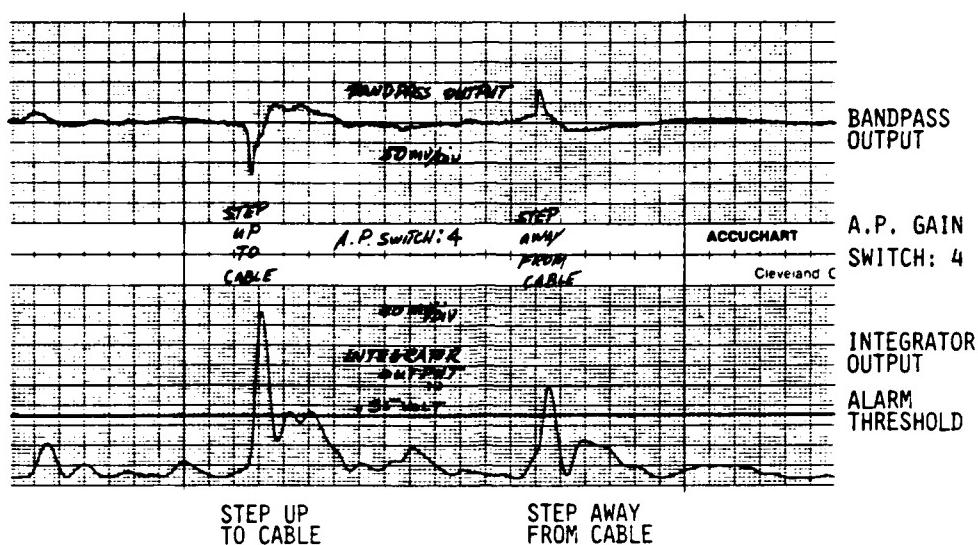


Figure 3-1 WALK TEST - ANDREW RX4-3 RADIAx CABLE

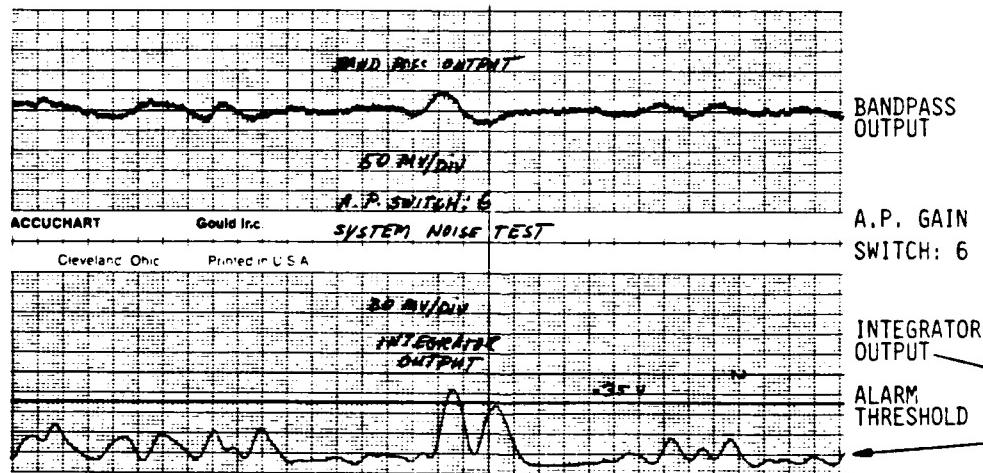


Figure 3-2 NOISE TEST - ANDREW RX4-3 RADIAx CABLE

utilization of available system gain. To illustrate this, the analog processor gain switch was raised from 4 to 6 and the quiet environment noise levels were recorded. A section of the recording (Figure 3-2) shows a false alarm caused by low frequency RF noise from the transmitter. To eliminate the possibility that external RF energy from other sources might be inducing the noise, the radiax cable was disconnected at the transmitter and terminated in a 50 ohm load (Figure 3-3A). The analog processor gain switch was set to its maximum of 11. The recording of the quiescent noise levels for this configuration (Figure 3-3B) verifies that nearly all system noise originates at the RFMS transmitter.

Conclusion: In relation to other cable types examined below, Andrew RX4-3 radiax cable is more expensive, cumbersome to handle, and difficult to manipulate around corners. The poor sensitivity of the cable and its mechanical bulk tend to rule out its practical use as a confined field antenna.

#### 4.0 CERT 285 (TIMES WIRE AND CABLE COMPANY)

The second type of radiax cable tested was a 200 foot section of CERT 285 cable, manufactured by Times Wire and Cable Company. The cable was incorporated into the system as per Figure 2-1A. Before performance testing was begun, the return loss ( $p$ ) at each end of the cable was measured by means of a network analyzer. At the transmit end,  $p$  measured -27dB, while at the receive end of the cable  $p$  measured -26dB. The RF power at both ends of the cable was also checked: at the transmit end +10.2 dBm of power was available, while at the receive end, the RF power was down to -17.5dBm. The transmission loss of CERT 285 at 915 MHz is therefore  $28\text{dB}/200\text{ ft} = .14\text{dB/ft}$ . When installed in the RFMS system, the system sensitivity (i.e. analog processor gain switch) could be set to the maximum of 11 without noise being a problem. When the CERT 285 was walk tested, it was not possible to alarm the RFMS when the intruder was greater than 4

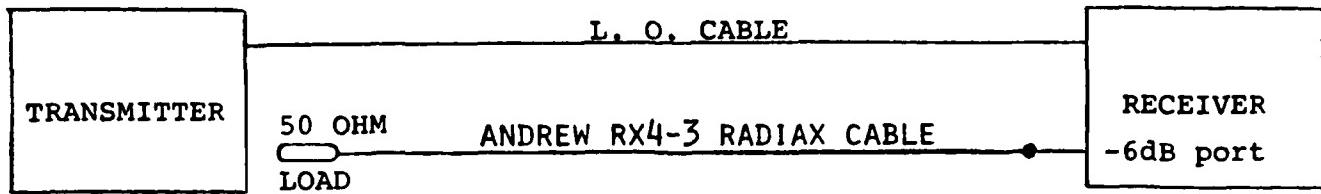


Figure 3-3A EXTRANEOUS NOISE TEST HOOKUP

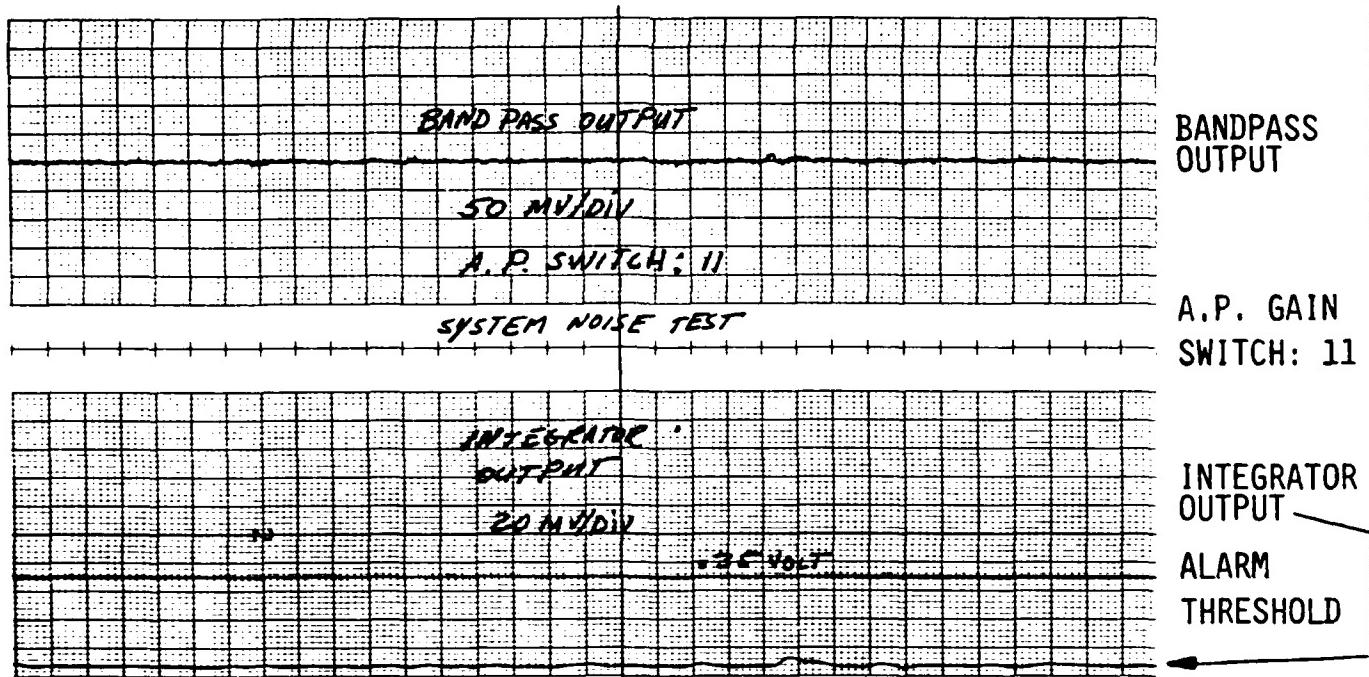


Figure 3-3B NOISE TRACE ANDREW RX4-3 CABLE

Figure 3-3 Noise Tests

inches away from the cable. From the above test results, one is forced to conclude that the high transmission loss through the cable is not due to radiation or mismatching, but rather from dissipation. The low amount of radiation and poor sensitivity of this cable tend to make it inappropriate for use as an intrusion sensor. A recording of the perturbation when stepping up to and away from the cable (within 4 inches) is given in Figure 4-1.

## 5.0 TWIN LEAD

### 5.1 General Theory

Of the three types of cable considered, twin lead has the advantage of ease of handling and low cost. The cable examined in this study was standard 300 ohm twin lead used in TV applications.

Originally, the twin lead was to be operated in the balanced mode, and for this purpose, baluns to match 50 ohms unbalanced to 300 ohms balanced were constructed. The baluns were attached to each end of a 20 foot section of twin lead and the cable assembly was installed into the RFMS system as per Figure 2-1A. When walk testing was performed on the cable, the results were negative; the ability of the cable to detect moving intruders at a distance beyond one inch was minimal. However, this is a correct result since the far field of a balanced transmission line is zero.

The alternative to the above result was to operate the twin lead in an unbalanced mode; that is, only one side of the transmission line would be energized while the other side would be connected directly to RF ground. The input impedance of the twin lead operated in this manner was measured by a network analyzer and verified to be close to 300 ohms. In order to match the 50 ohm impedances of the RFMS units to 300 ohms, three types of transformers were considered. The first two constructed

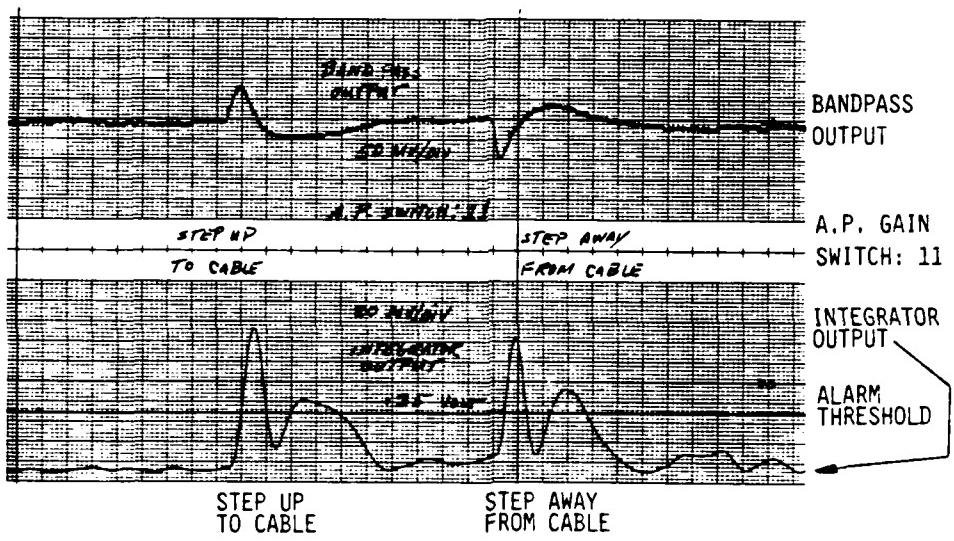


Figure 4-1 WALK TEST CERT 285 RADIAx CABLE

involved the use of microstrip cards. These were found to be critical with respect to circuit dimensions and not suitable for all methods of operating the twin lead that would be examined. The third transformer design was found to be satisfactory for all possible connections: It is a specially made coaxial line machined out of aluminum rod. The unit, illustrated in Figure 5-1, is a quarter wavelength long at 915 MHz and utilizes air as the dielectric between the inner and outer conductors. The characteristic impedance ( $Z_o$ ) of the line is given by the formula  $Z_o = \sqrt{Z_i Z_L}$ , where  $Z_i$  is the desired input impedance and  $Z_L$  is the load impedance to be matched. Mounting holes were also provided for the addition and removal of reflector plates.

The twin lead can be connected to the coaxial line matching transformers and reflector plates in several ways as shown in Figure 5.2.

The tests were begun with a single cable as per Figures 5-2A and 5-2B. The transmission line was supported 3 feet above the floor on wooden stands. A quick profile of the cable sensitivity would be taken with a parallel walk test, which was conducted by walking 3 feet outboard along the length of the cable. Then perpendicular walk testing would be performed at selected points along the length of the cable. The test results showed that the configuration of Figure 5-2B provides roughly 6dB more sensitivity to motion while being less sensitive to oscillator noise than that of 5-2A. This is most likely the result of each half of the line being terminated only at one end.

However, the results of both configurations show the cables to be "hot" on the ends and "cool" in the middle. Several references on antenna theory state the following about long wire antennas (see bibliography at the end of this section). The main lobe of a half wave antenna propagates from the antenna at 90° with respect to the axis. However, as the length of the antenna is increased the main lobes tend to come off the antenna at

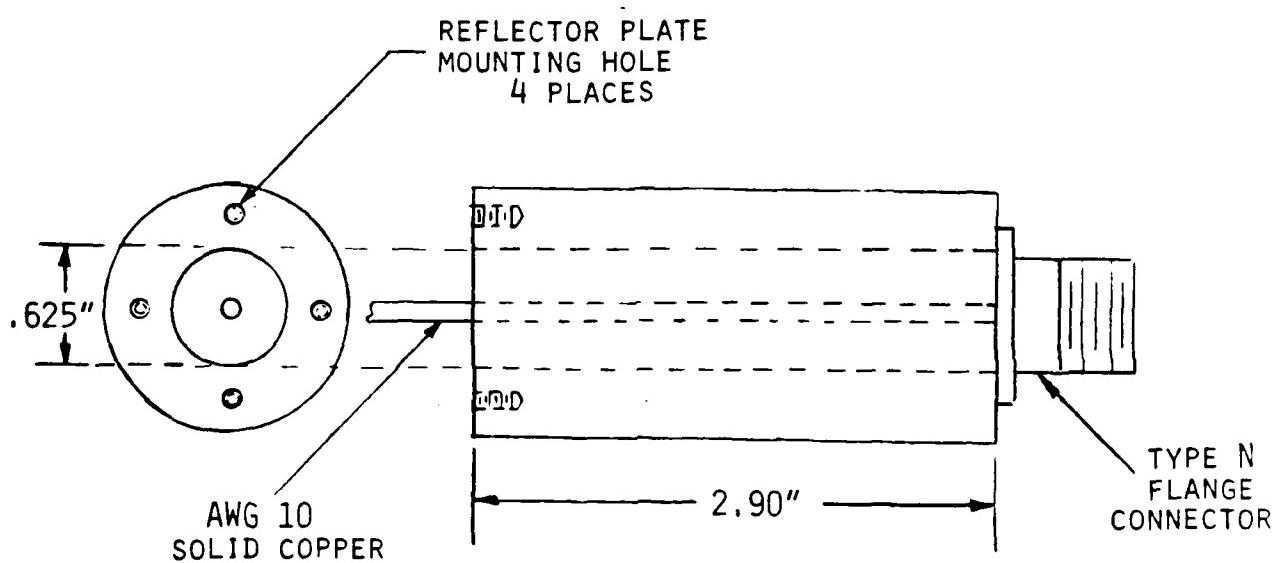


Figure 5-1. 50 OHM TO 300 OHM COAXIAL MATCHING TRANSFORMER



Figure 5-2A

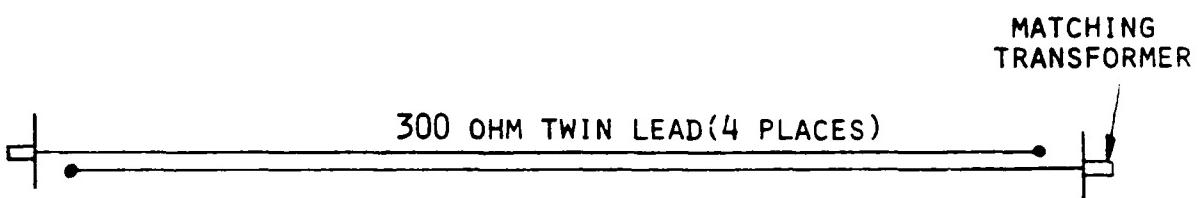


Figure 5-2B

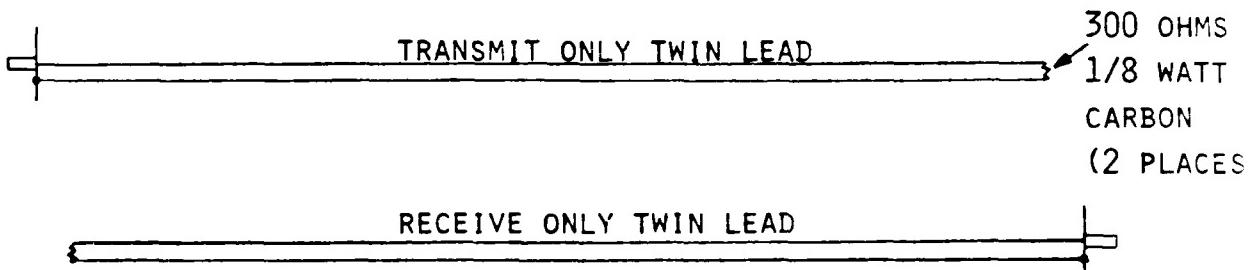


Figure 5-2C

Figure 5-2. TWIN LEAD HOOKUP CONFIGURATIONS

lesser angles. This effect is illustrated for antenna lengths from  $1/2$  to 8 wavelengths long in Figure 5-3. Each antenna with its standing wave current distribution is shown below its radiation pattern. The position of the sinusoidal curve above or below the line represents the direction of the antenna current, while the vertical displacement of the curve is proportional to the relative magnitude of the current. For example, beneath the spatial pattern of Figure 5-3A, the distribution of current on a dipole antenna is pictured, while in Figure 5-3H, the distribution of current is that of an antenna 4 wavelengths long. The cables under test for this study were about 200 wavelengths long. The three dimensional radiation field for each antenna is obtained by mentally rotating the topmost pattern in each figure about the horizontal axis.

The radiation patterns shown in Figure 5-3 are for standing wave currents only. If, however, the antenna current is a pure traveling wave, the resultant patterns differ in that the backward lobes are severely attenuated, while leaving the forward lobes dominant. Any combination of traveling and standing wave currents on an antenna will therefore result in more or less attenuation of the backward lobes. A reflector can be placed at one or both ends of the cable to restrict radiation beyond the cable ends, depending upon site requirements. A reflector so placed at the end of a long wire antenna will propagate the main lobes back along the direction of the cable. Because the intensity of the lobes is greatest at the ends, so likewise the sensitivity of the system to motion is greatest at the ends. The exact shape and intensity of the spatial pattern is difficult to obtain without the aid of specialized equipment and a suitable testing range. Routine observations tend to show that there are two fields associated with the twin lead long wire antenna: a confined field surrounding the cable throughout most of its length, and a spatial field commonly called "end fire" emanating off both ends. An estimate of the free space pattern based on these observations is given in the profile view of Figure 5-4.

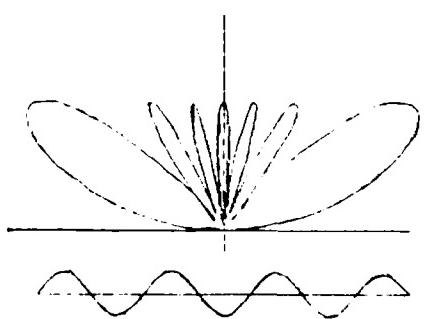


Figure 5-3G . 7 STANDING WAVES

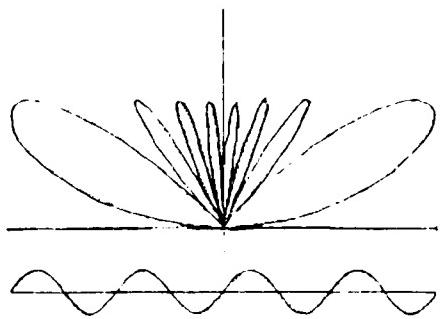


Figure 5-3H . 8 STANDING WAVES

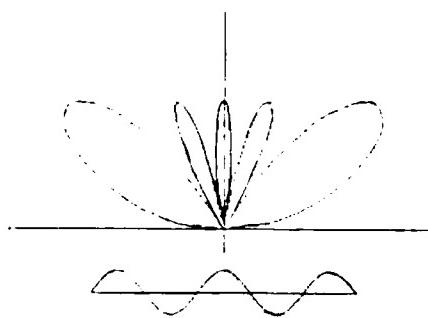


Figure 5-3E . 5 STANDING WAVES

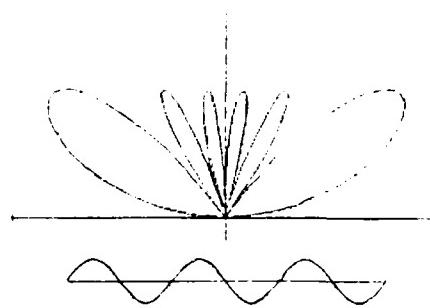


Figure 5-3F . 6 STANDING WAVES

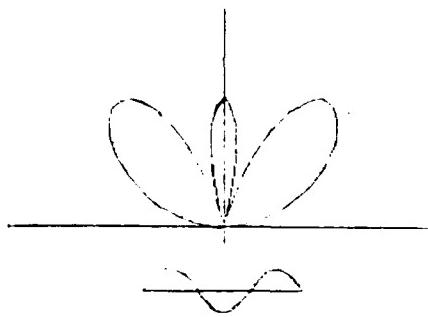


Figure 5-3C . 3 STANDING WAVES

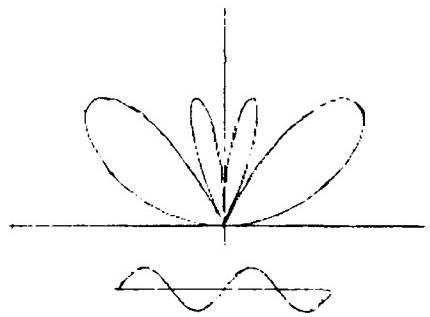


Figure 5-3D . 4 STANDING WAVES

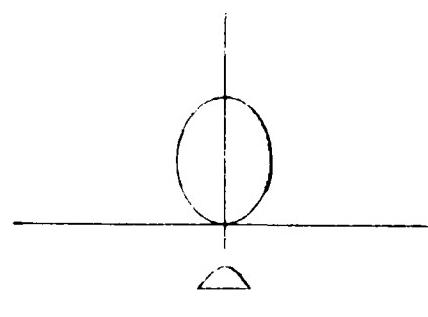


Figure 5-3A . 1 STANDING WAVE

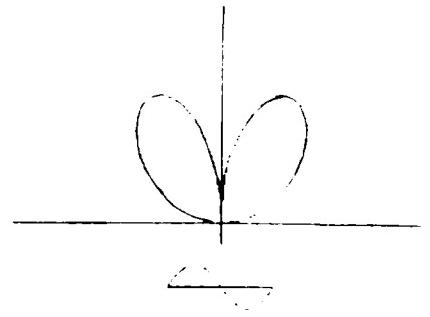


Figure 5-3B . 2 STANDING WAVES

Figure 5-3. IDEAL FREE SPACE PATTERNS FOR LONG WIRE ANTENNAS WITH STANDING CURRENTS

If the reflector plates were absent, the intensity profile at each end of the cable would tend to appear as a four leaf clover. The three dimensional radiation pattern of the cable is obtained by mentally rotating the lobes of Figure 5-4 about the cable axis.

The practical result of the two fields mentioned above is that within one foot of the cable, the confined field along the cable will predominate; beyond that distance, however, the spatial fields radiating off the ends of the cable predominate and have more or less the same effect as two discrete spatial antennas placed at the ends of the cable.

The walk test data for cable configurations 5-2A and 5-2B is given in Figures 5-5 through 5-8. The parallel walk test data recorded on the strip charts (Figures 5-5 and 5-7), show the tendency of the cables to be more sensitive at the ends.

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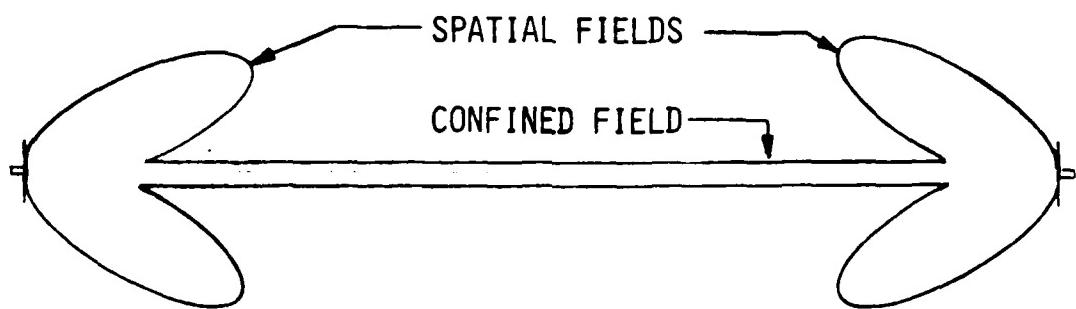


Figure 5-4. ESTIMATED FIELDS OF LONG TWIN LEAD ANTENNA  
WITH END REFLECTORS

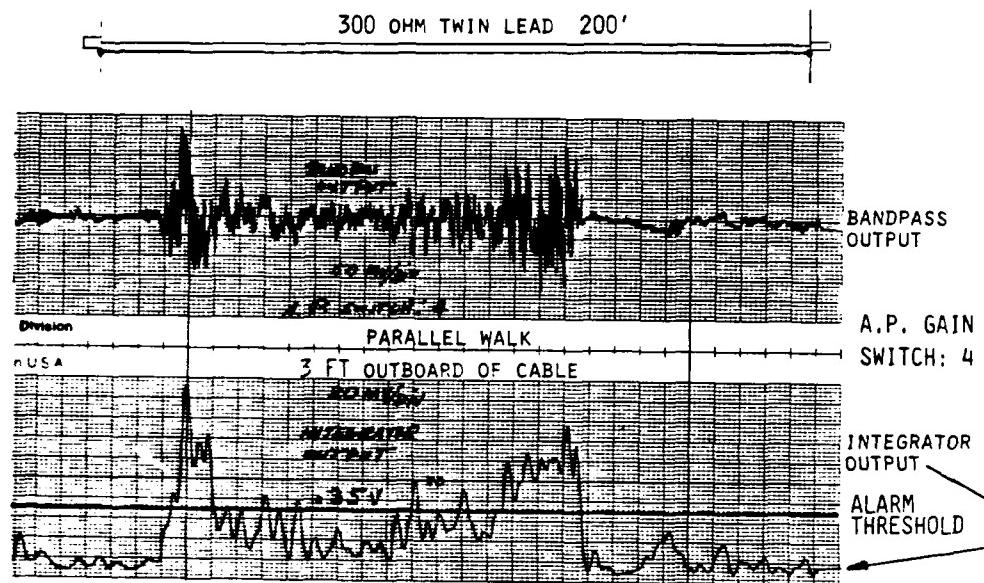


Figure 5-5. PARALLEL WALK TEST DATA FOR TWIN LEAD CONNECTED AS SHOWN.

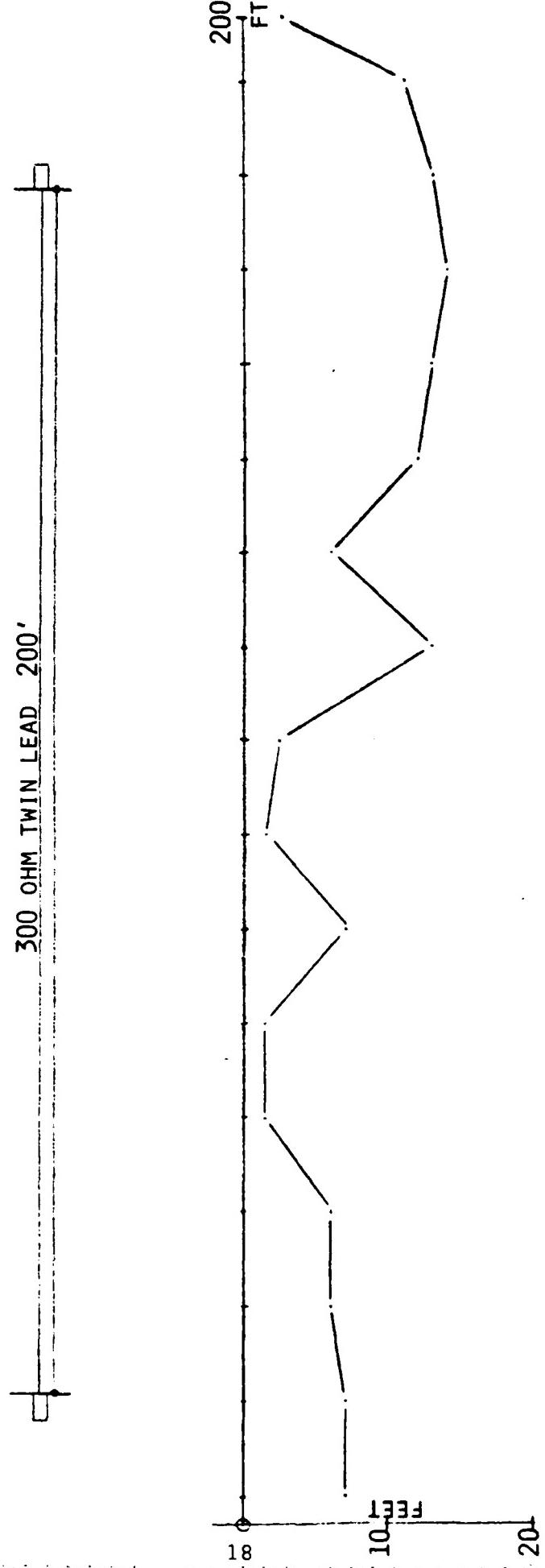


Figure 5-6. PERPENDICULAR WALK TEST DATA FOR TWIN LEAD CONNECTED AS SHOWN

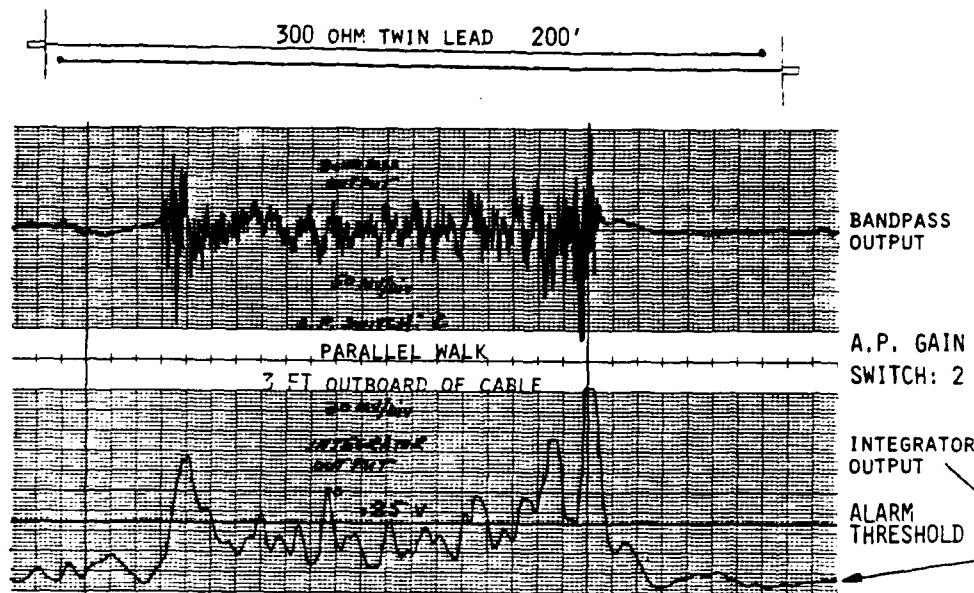


Figure 5-7. PARALLEL WALK TEST DATA FOR TWIN LEAD CONNECTED AS SHOWN.

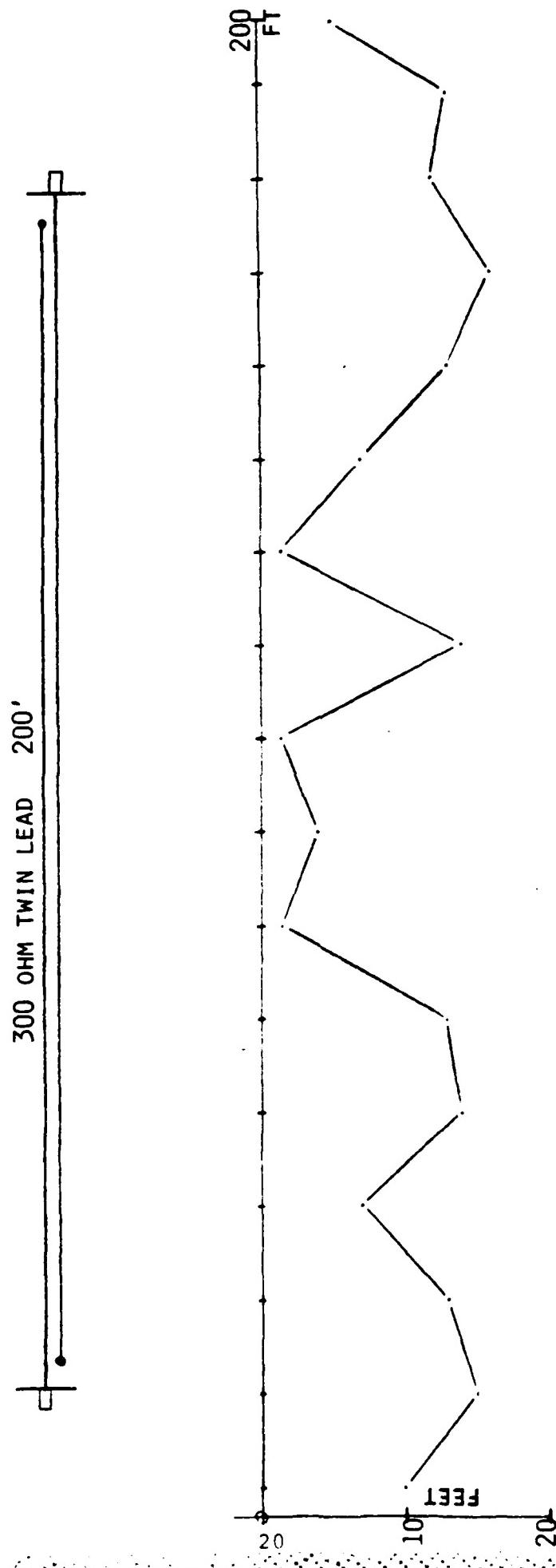


Figure 5-8. PERPENDICULAR WALK TEST DATA FOR TWIN LEAD CONNECTED AS SHOWN

## 5.2 Twin Lead Applications

The use of two terminated twin lead cables, one for transmitting, the other for receiving (Figure 5-2C), allows for more variation in deployment of the sensors. The integration of two cables into the system was illustrated in Figure 1-1B above. Although many deployments were tried, only the three most significant ones will be discussed. These are dubbed the trolley mount, the wall mount, and the perimeter mount.

### 5.2.1 Trolley Mount

The trolley mount setup is shown in Figure 5-9. As shown by the photograph, the transmit and receive cables were laid over wooden yardarms throughout the length of the lab space, with the average height of the cables being 6.5 feet from the floor. The effect of the horizontal spacing of the two cables from each other was examined, and the optimum results were obtained when the separation was from 13 to 30 inches.

Two configurations of the trolley wire arrangement were considered and tested: The first was with the RFMS transmitter and receiver at opposite ends of the lab, while the other was with the transmitter and receiver at the same end of the lab. The performance of the former was found to be superior. Figures 5-10 and 5-11 are the perpendicular walk test data for the two configurations. The horizontal spacing of the cables, the transmit power and the receiver gain in both cases are identical. With the receiver and transmitter at opposite ends of the lab, there is good sensitivity and uniform coverage throughout the length of the cable (Figure 5-10), while the coverage of units placed at the same end of the lab attenuates rapidly beyond 100 feet (Figure 5-11). The latter arrangement is therefore not recommended.

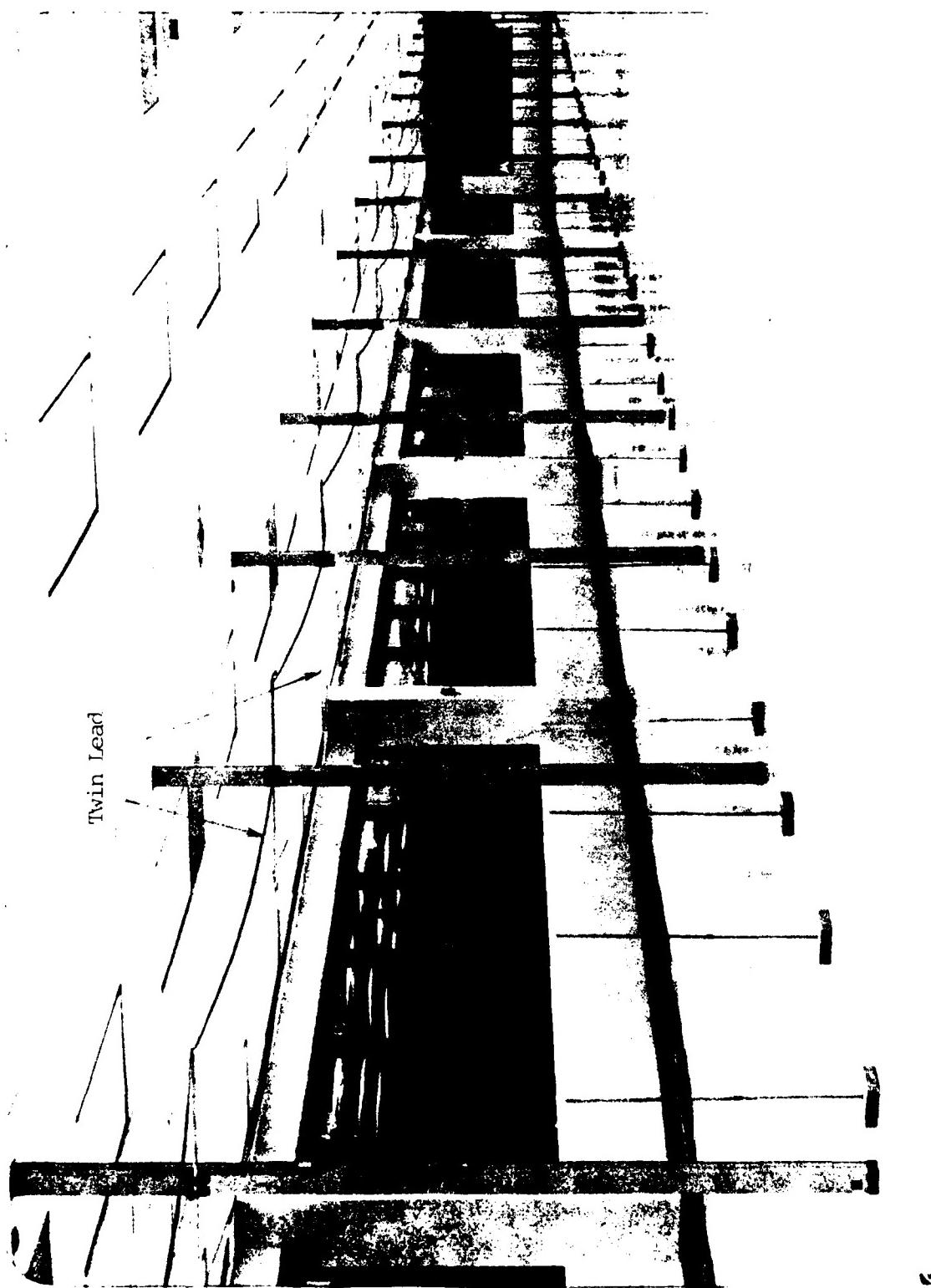


Figure 5-9. Cable Deployment for Trolley Mount Test Configuration

TROLLEY WIRE MOUNT

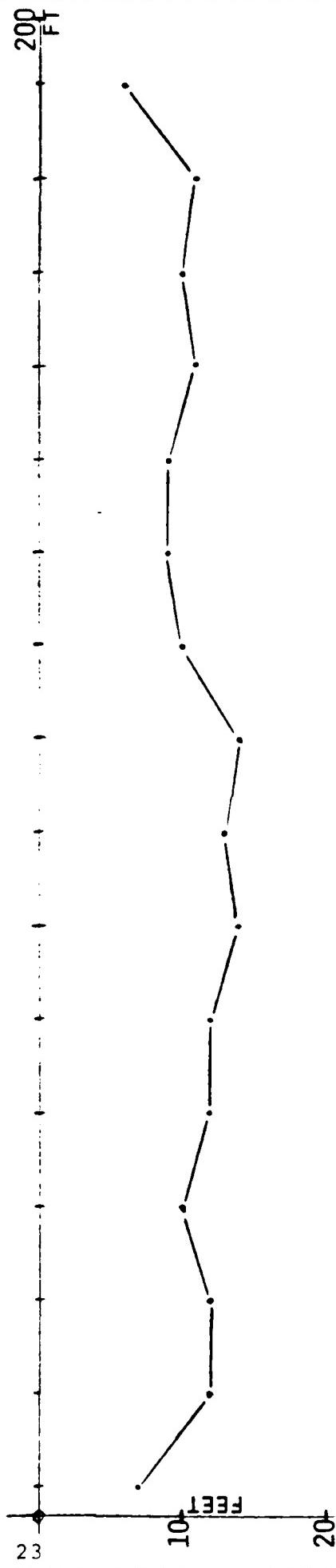
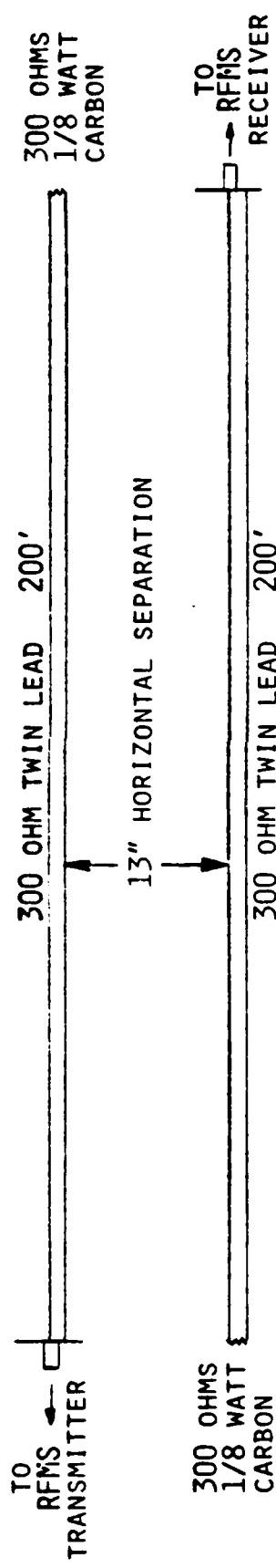


Figure 5-10. PERPENDICULAR WALK TEST DATA FOR TROLLEY WIRE CONFIGURATION SHOWN ABOVE

TROLLEY WIRE MOUNT

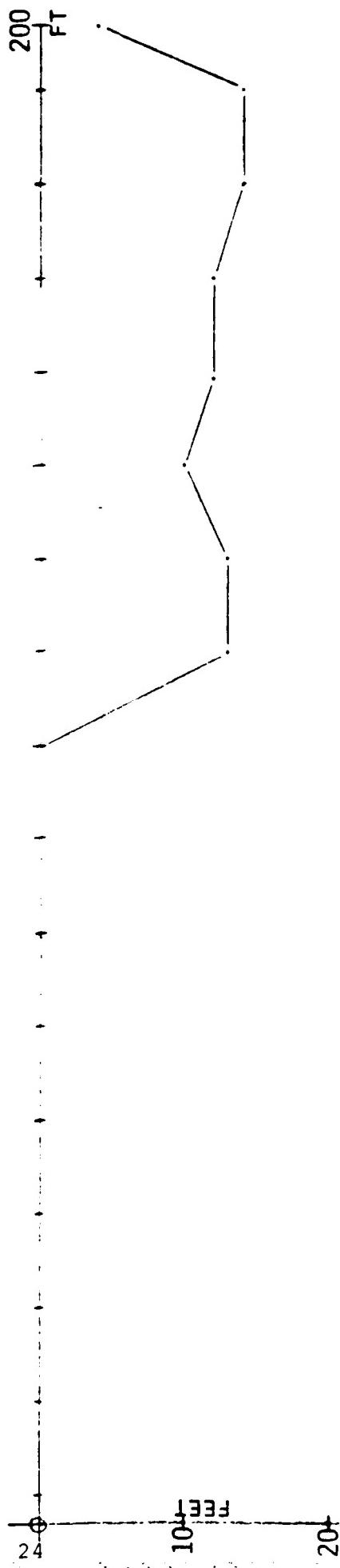
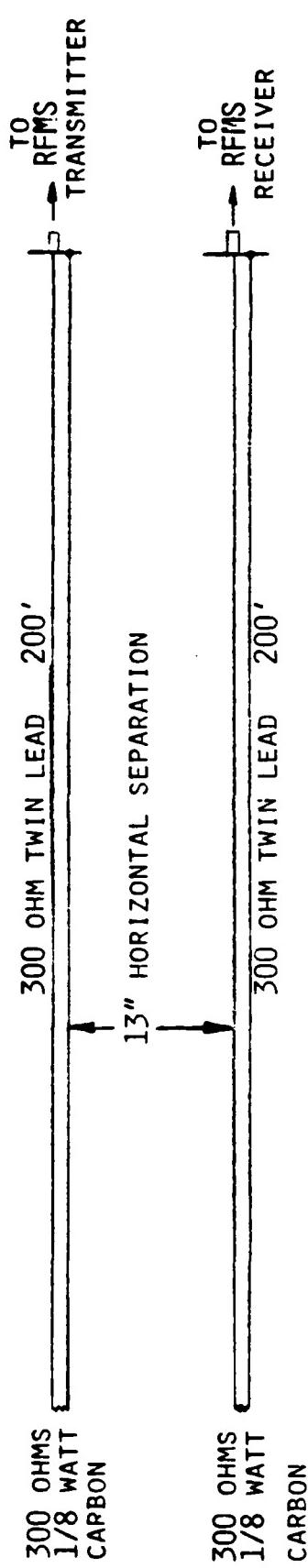


Figure 5-11. PERPENDICULAR WALK TEST DATA FOR TROLLEY WIRE CONFIGURATION  
SHOWN ABOVE

The results of trolley wire tests with (receiver and transmitter at opposite ends of the lab) are presented in Figures 5-12 to 5-19 inclusive. First, parallel walk test data at four separate distances from the receiver cable are presented in Figure 5-12 through 5-15. Next, Figures 5-16 through 5-18 gives the results of creeper tests at 1/4 , 1/2 , and 3/4 up the length of the cable from the transmitter end. The creeper test was performed by moving crosswise to the cable. Finally, Figure 5-19 is a recording of the quiescent noise of the trolley wire system. The analog processor gain switch was set to 5 for all of the above recorded data.

The trolley wire arrangement would be applicable for use in long corridors or shelf spaces where an overhead, out of reach installation is necessary.

#### 5.2.2 Wall Mount

The wall mount configuration is shown in Figure 5-20. The recommended separation of the cables is from 19 to 26 inches, which corresponds to 1.5 to 2 wavelengths at 915 MHz. For this configuration, the RFMS transmitter and receiver were at opposite ends of the lab, with the lower cable being driven by the transmitter. Parallel walk test data was recorded at distances of 1 ft, 3 ft and 6 ft outboard of the cables and is shown in Figures 5-21 through 5-23. Creeper testing was conducted at three points along the cable assembly and the recordings at the three locations is given in Figures 5-24 through 5-26. A photograph of a creeper test in progress is shown in Figure 5-27. A graph of the recorded perpendicular walk test data is presented in Figure 5-28, and a recording of the quiescent baseline noise for this configuration is shown in Figure 5-29. The analog processor gain switch was set to 5 for all of the above tests.

The data shows that the wall mount configuration would be applicable in corridors or shelf spaces where out-of-reach

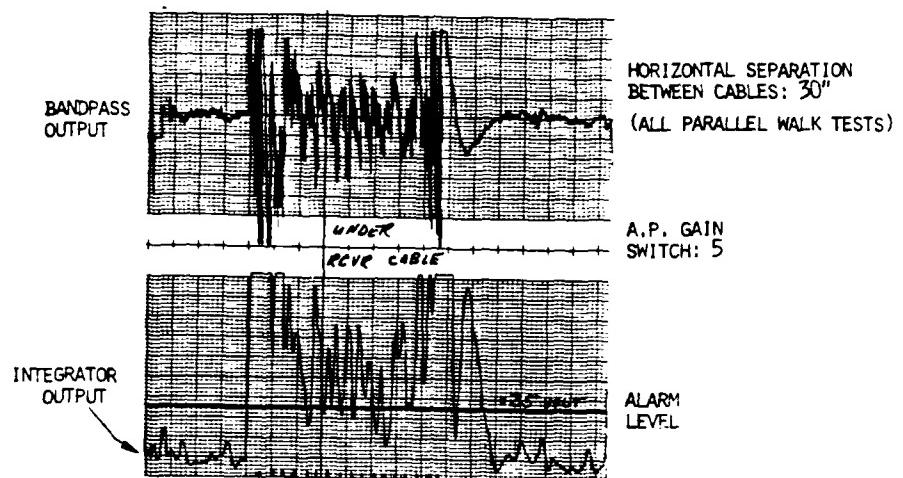


Figure 5-12. TROLLEY WIRE PARALLEL WALK TEST (UNDER RCVR CABLE)

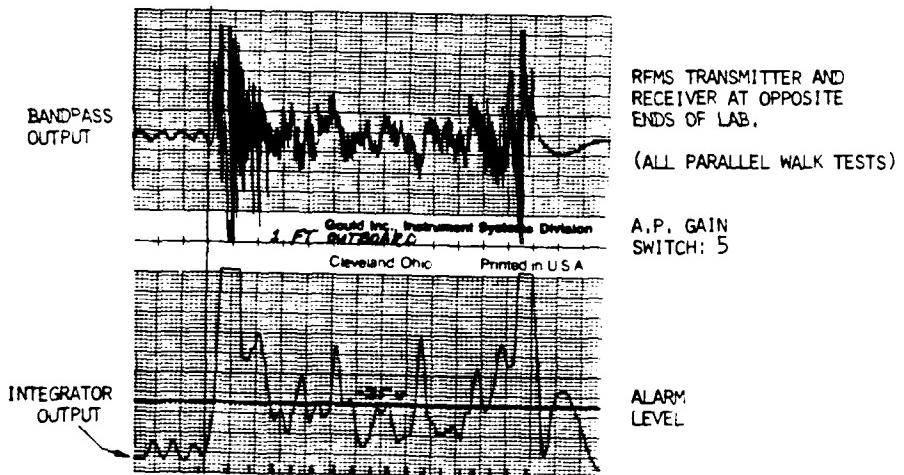


Figure 5-13. TROLLEY WIRE PARALLEL WALK TEST (1' OUTBOARD OF RCVR CABLE)

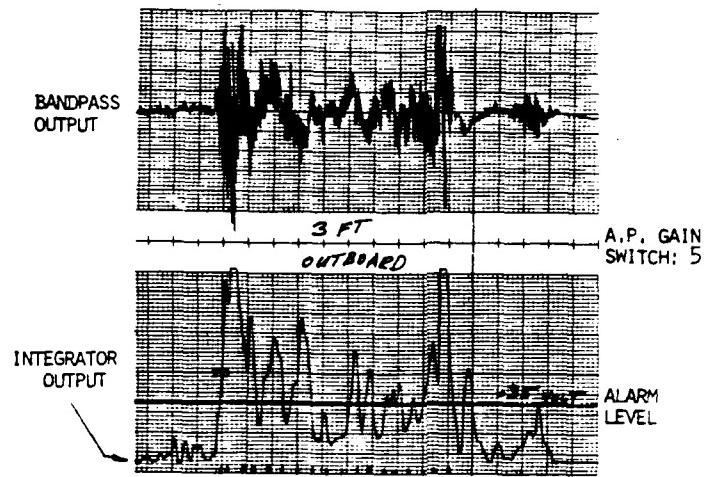


Figure 5-14. TROLLEY WIRE PARALLEL WALK TEST (3' OUTBOARD OF RCVR CABLE)

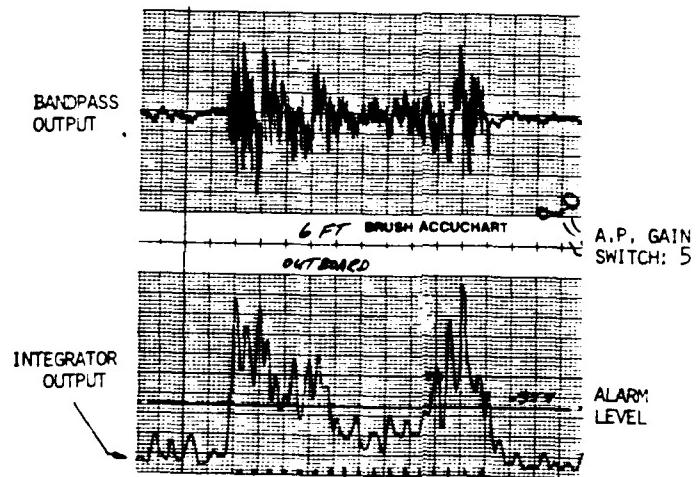


Figure 5-15. TROLLEY WIRE PARALLEL WALK TEST (6' OUTBOARD OF RCVR CABLE)

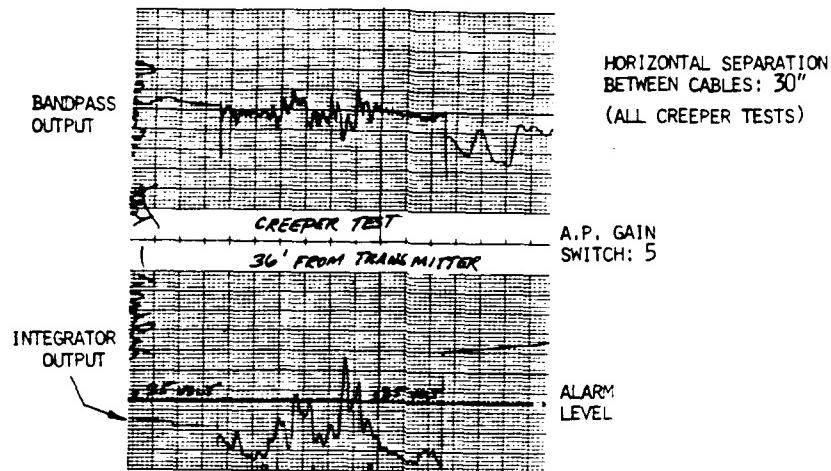


Figure 5-16. TROLLEY WIRE CREEPER TEST(36' FROM TRANSMITTER)

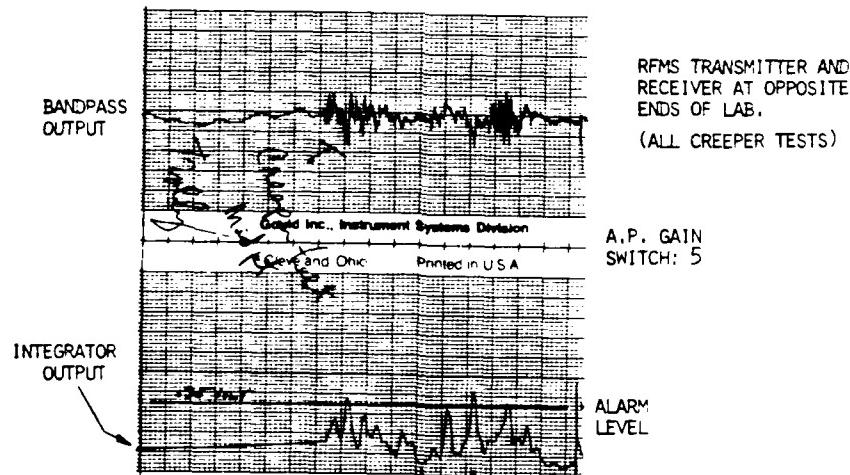


Figure 5-17. TROLLEY WIRE CREEPER TEST (MIDPOINT OF CABLE)

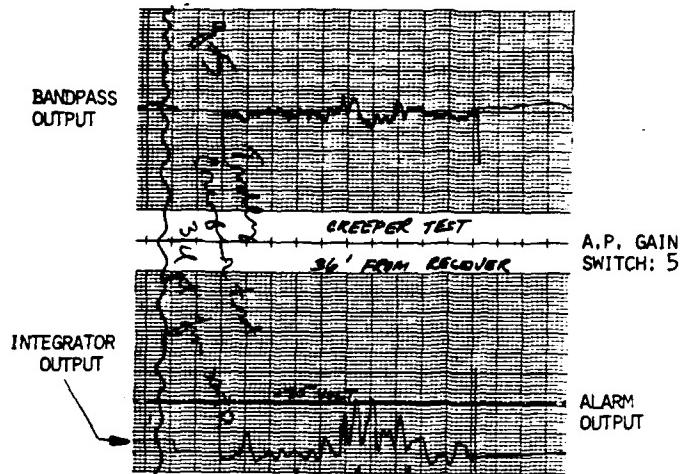


Figure 5-18. TROLLEY WIRE CREEPER TEST (36' FROM RECEIVER)

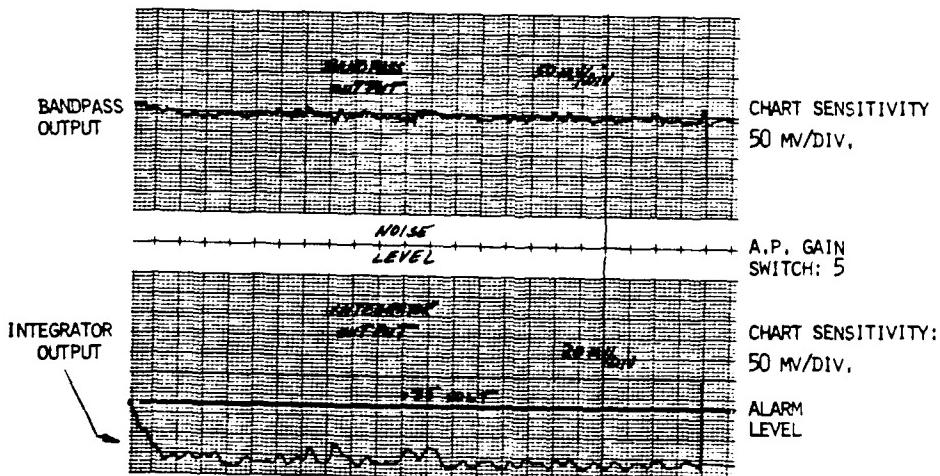


Figure 5-19. BASELINE NOISE - TROLLEY WIRE CONFIGURATION

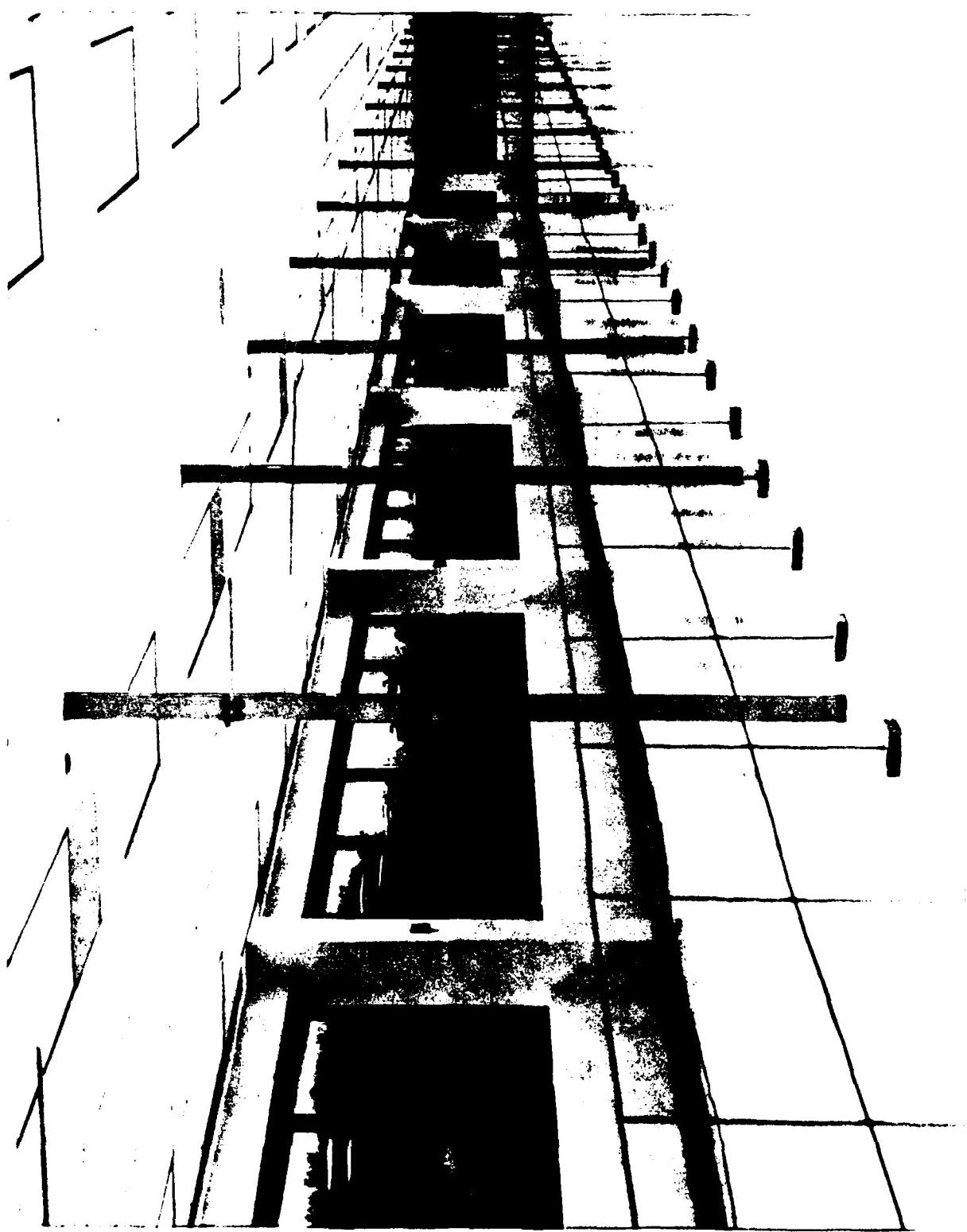


Figure 5-20. Cable Deployment for Wall Mount Test Configuration

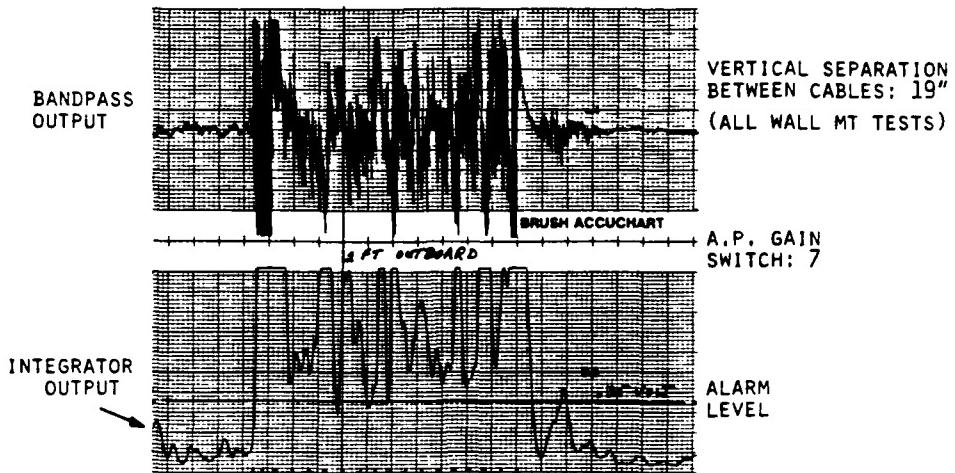


Figure 5-21. WALL MOUNT - PARALLEL WALK TEST (1' FROM CABLES)

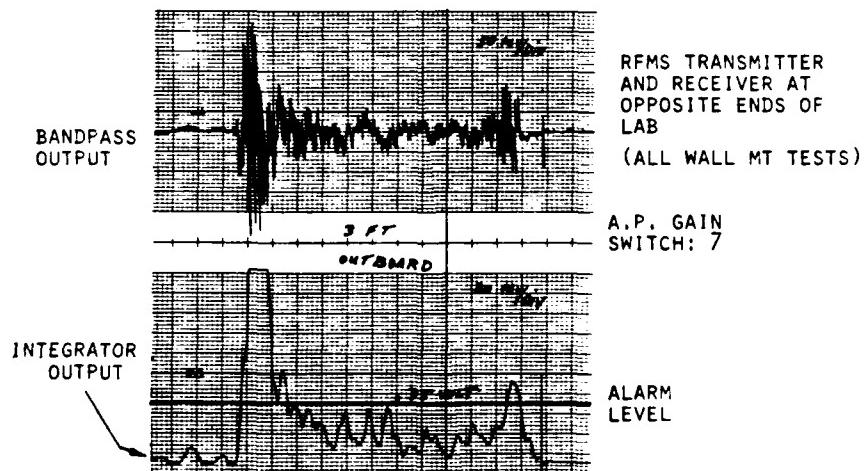


Figure 5-22. WALL MOUNT PARALLEL WALK TEST (3' FROM CABLES)

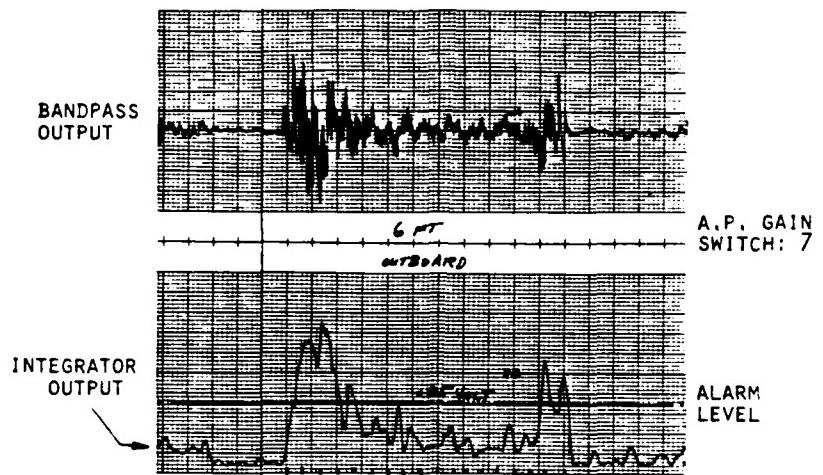


Figure 5-23. WALL MOUNT PARALLEL WALK TEST (6' FROM CABLES)

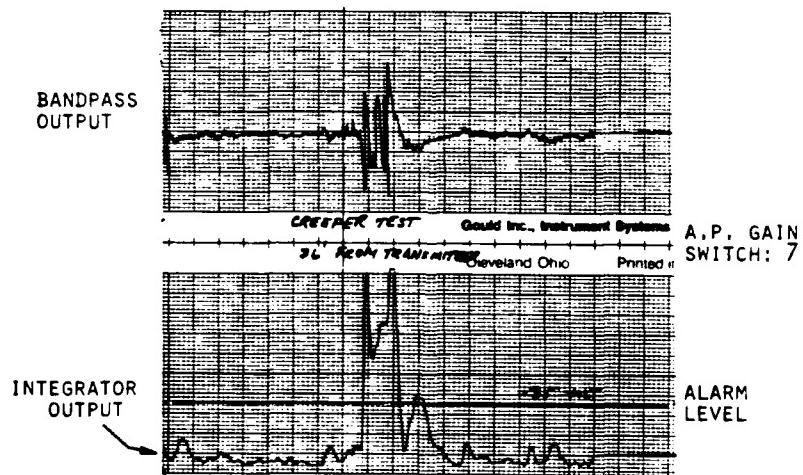


Figure 5-24. WALL MOUNT CREEPER TEST (36' FROM TRANSMITTER)

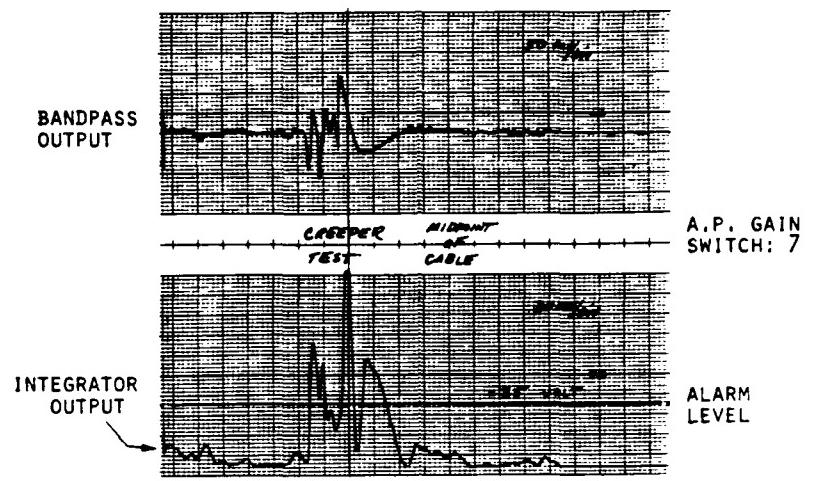


Figure 5-25. WALL MOUNT CREEPER TEST (MIDPOINT OF CABLES)

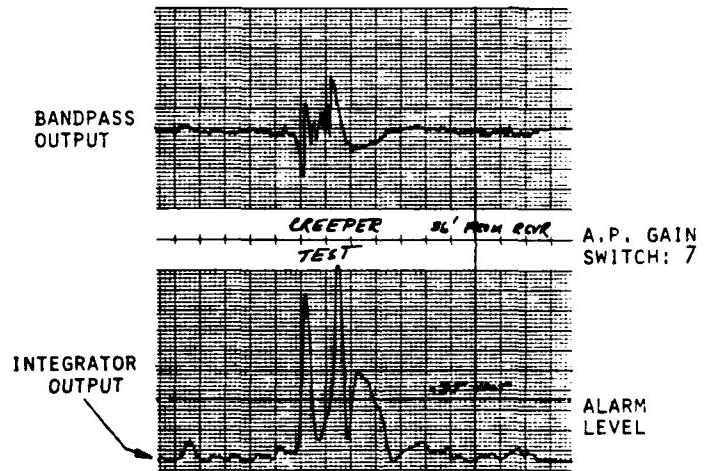


Figure 5-26. WALL MOUNT CREEPER TEST (36' FROM RCVR)

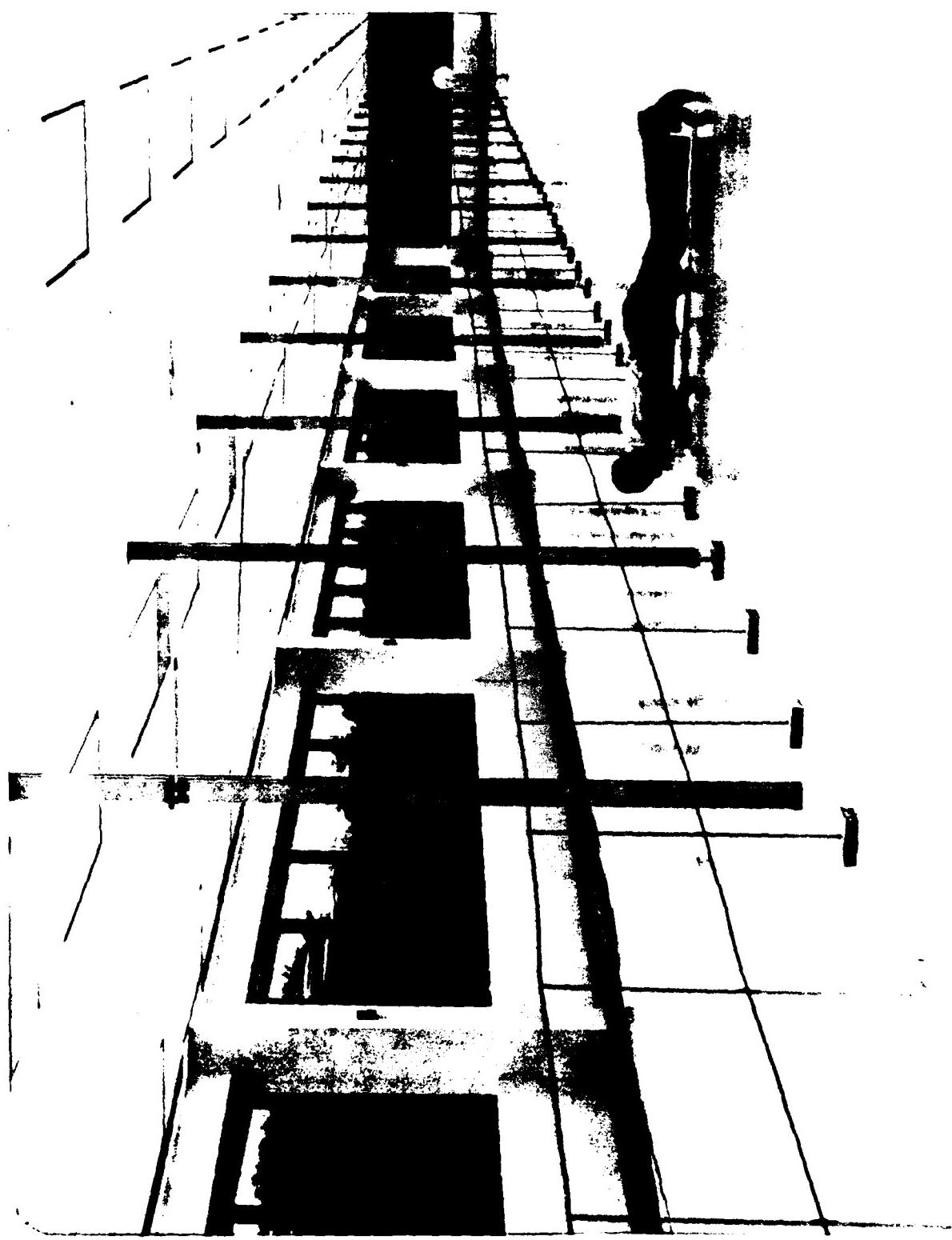


Figure 5-27. Creeper Approaching Wall Mount Configuration

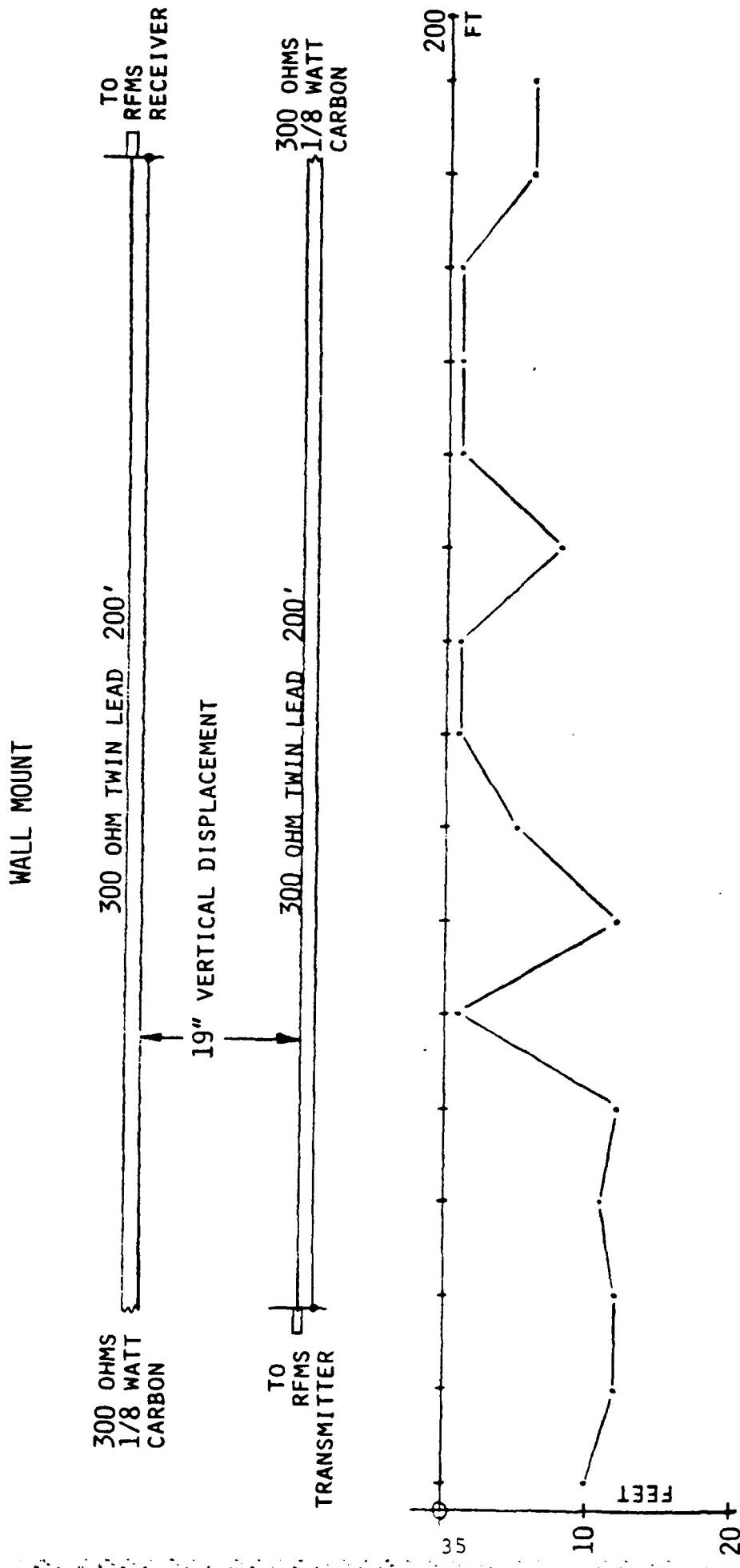


Figure 5-28. WALL MOUNT PERPENDICULAR WALK TEST DATA

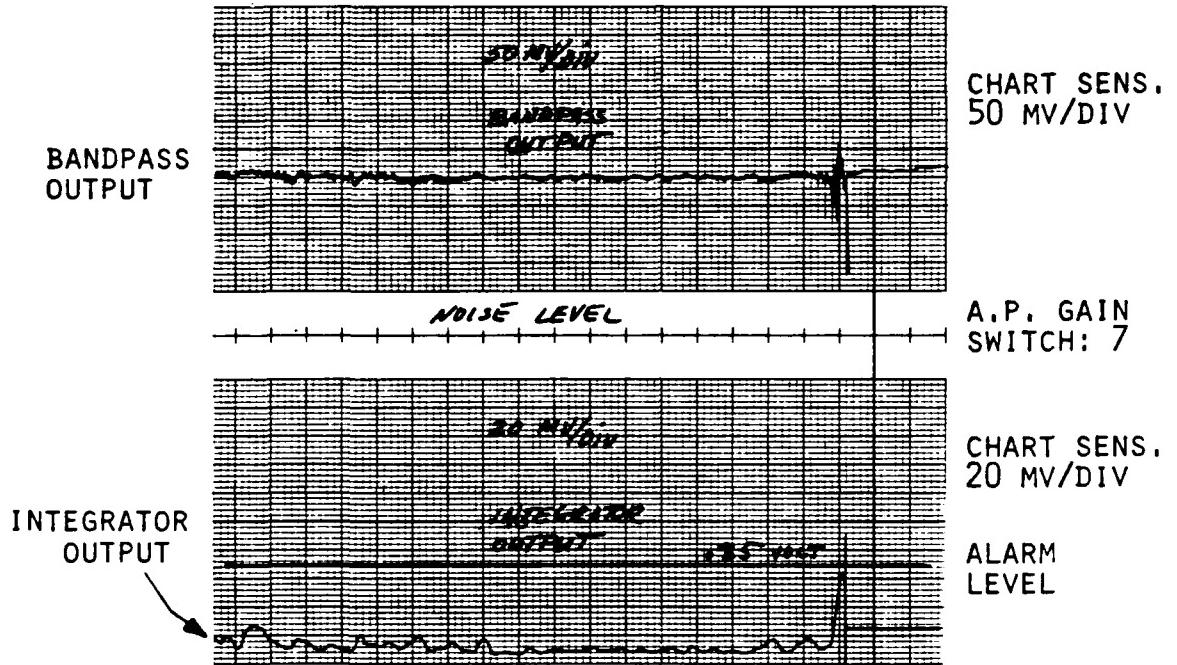


Figure 5-29. WALL MOUNT QUIESCENT NOISE TRACE

installation is not mandatory, but good creeper sensitivity is a must. Another application would be as a perimeter intrusion device requiring good creeper sensitivity at the enclosure limits.

#### 5.2.3 Perimeter Mount

The perimeter mount configuration was deployed by securing the receiver twin lead along the windows on one side of the lab, and securing the transmit lead along the wall on the opposite side. When deployed in this manner, the horizontal separation of the two cables was 28 feet, with a typical height of 7 feet from the floor. The cables were attached to their respective RFMS units at opposite ends of the lab.

This array was tested by first walking alongside one of the two walls, then moving out a quarter of the way (7 feet) for the next walk, etc., and concluding alongside the other wall. Figures 5-30 through 5-34 inclusive, show the recordings of these four tests. The data shows good spatial coverage throughout the lab. An additional walk test was also performed outside of the lab space, 3 feet away from the wall supporting the transmit cable. This was done to record the effect of personnel movements outside of an area where the perimeter array might be used. The wall supporting the transmit cable consists of two layers of sheetrock attached to metal studwork. The result of this test shows a fair amount of RF energy outside of the lab space, and hence, susceptibility to outside movements (Figure 5-35).

A quiescent noise trace of the perimeter mount configuration is shown in Figure 5-36.

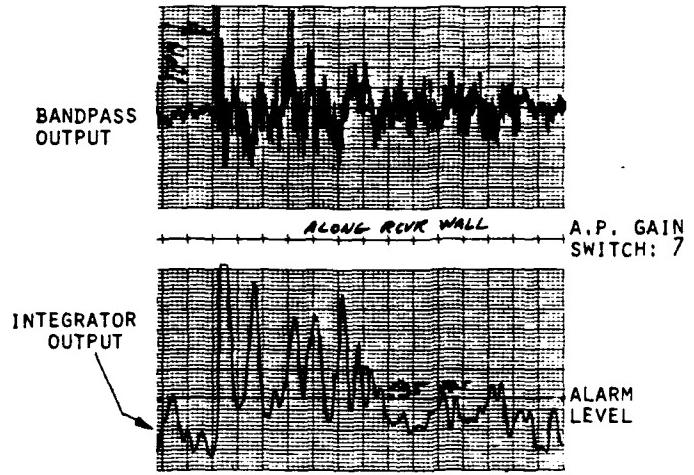


Figure 5-30. PERIMETER MOUNT PARALLEL WALK TEST  
(ALONG WALL SUPPORTING RECEIVER CABLE)

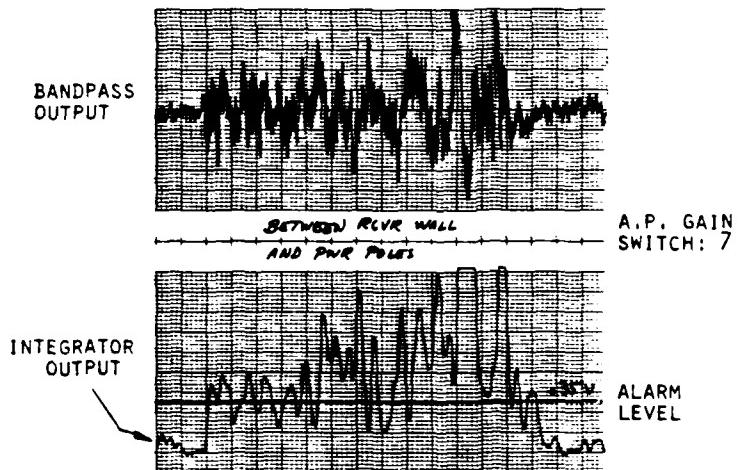


Figure 5-31. PERIMETER MOUNT PARALLEL WALK TEST  
(7' FROM WALL SUPPORTING RECEIVER CABLE)

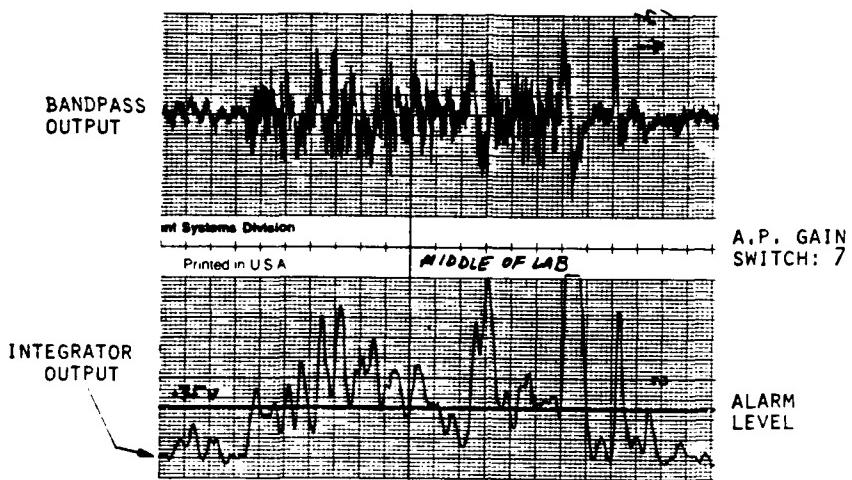


Figure 5-32. PERIMETER MOUNT PARALLEL WALK TEST  
(MIDWAY BETWEEN TRANSMIT AND RECEIVE CABLES)

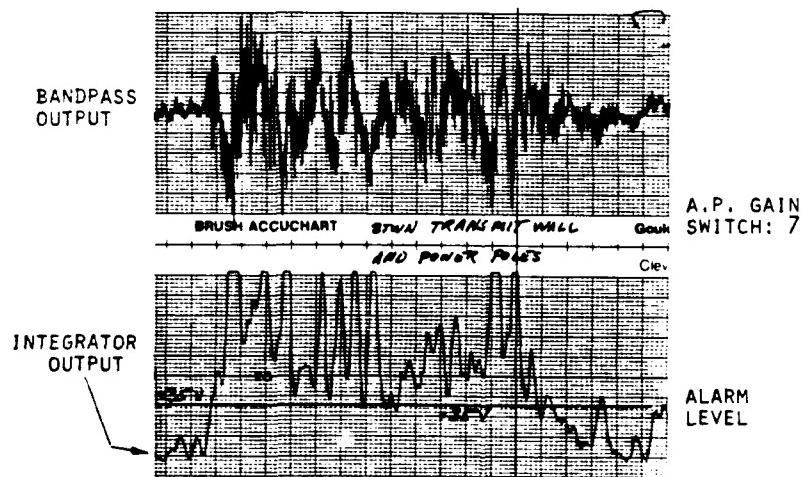


Figure 5-33. PERIMETER MOUNT PARALLEL WALK TEST  
(7' FROM WALL SUPPORTING TRANSMIT CABLE)

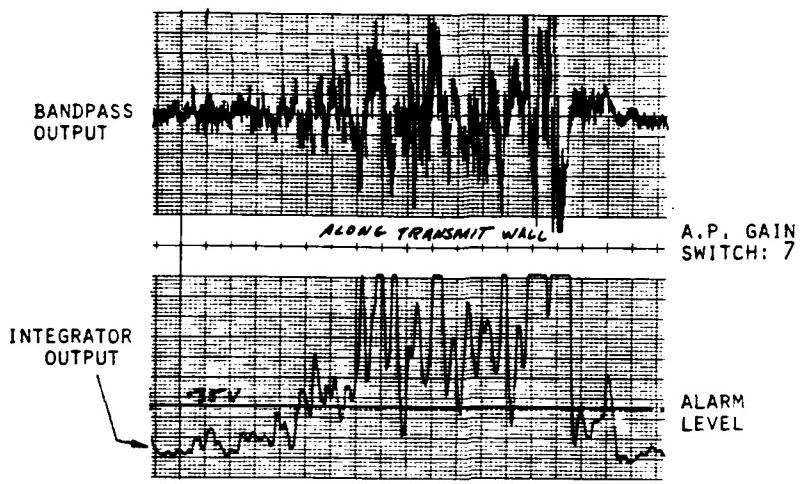


Figure 5-34. PERIMETER MOUNT PARALLEL WALK TEST  
(ALONG WALL SUPPORTING TRANSMIT CABLE)

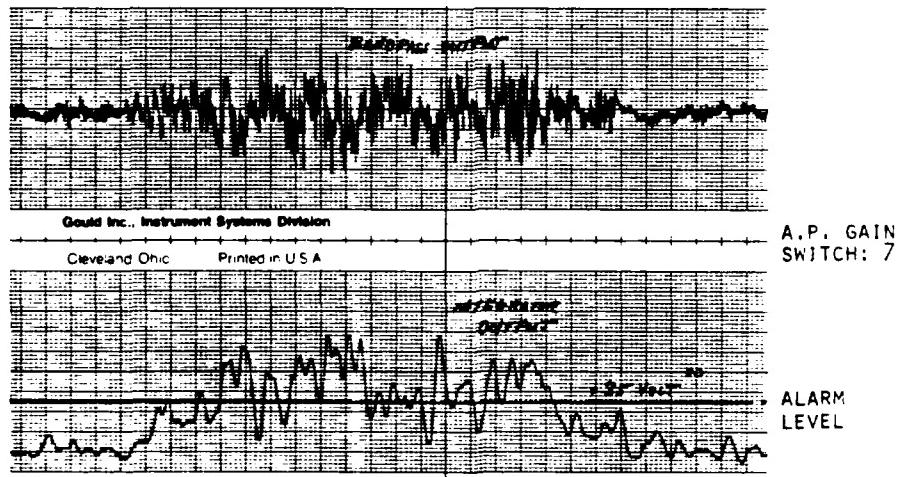


Figure 5-35. PERIMETER MOUNT PARALLEL WALK TEST  
(3' OUTSIDE OF WALL SUPPORTING TRANSMIT CABLE)

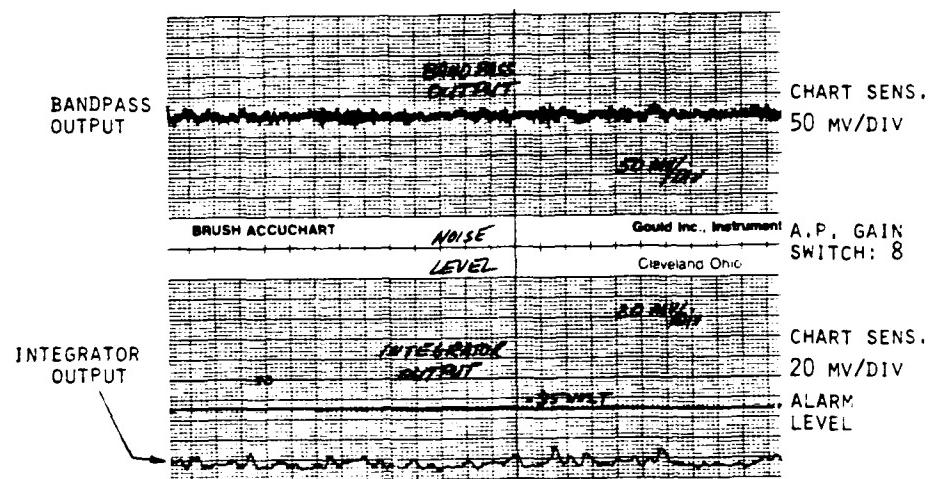


Figure 5-36. PERIMETER MOUNT BASELINE NOISE TRACE

## 6.0 MODIFIED TWIN LEAD ANTENNA

The basic twin lead cable antennas described above (Figures 5-2A and 5-2B), suffer from the phenomenon of "hot" ends and a "cool" center section. An attempt was made to vary the distribution of the RF currents on the cable and thereby change the radiation characteristic. An instantaneous distribution of currents on a long wire antenna is shown again in Figure 6-1. The displacement of the dashed curve from the antenna gives the magnitude of the instantaneous current at that point. The position of the dashed curve above or below the cable indicates the direction of the current. The theoretical far field patterns of such a current distribution are given in Figure 5-3.

If the cable is modified as in Figure 6-2, the theoretical current distribution would be as shown. The far field idealized free space pattern for several dipoles in series is displayed in Figure 6-3. The important thing to note about the pattern is that the main lobe is always normal to the wire for any number of dipoles.

To try out this concept, alternate sections of a 200 foot long twin lead cable were folded in the middle and secured at the ends with cable ties. When the process was completed, the formerly 200 foot long cable measured only 85 feet. A photograph of the finished cable on the lab space floor is given in Figure 6-4. Though not shown in the photograph, to each end of the cable was attached just enough straight twin lead to reach the ends of the lab. The cable assembly was placed on the wooden stands and parallel walk tested. The recording of this test (Figure 6-5) seems to indicate that the desired objective was somewhat accomplished. Only one end of the cable appears "hotter" than the rest, while the remainder appears uniform. It is not known how this cable arrangement would work for longer lengths since for every foot of folded cable, 2.4 feet of straight twin lead would be needed. The loss factor of twin lead in this case may be prohibitive.

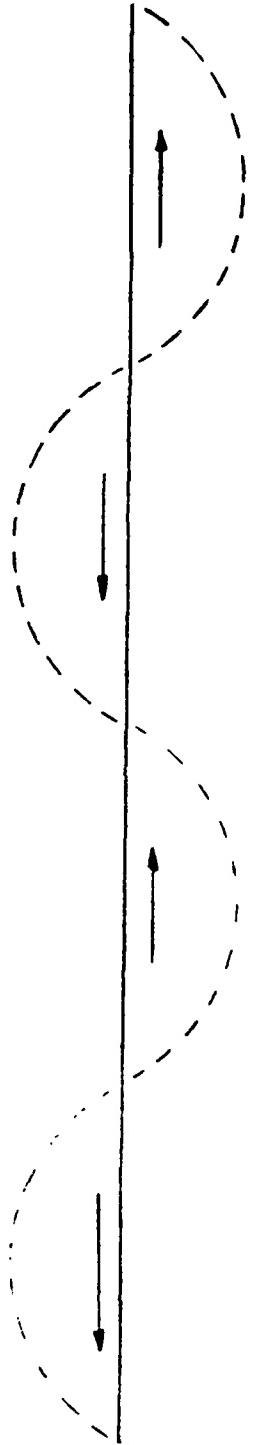


Figure 6-1. INSTANTANEOUS CURRENT DISTRIBUTION OF REGULAR LONG WIRE ANTENNA

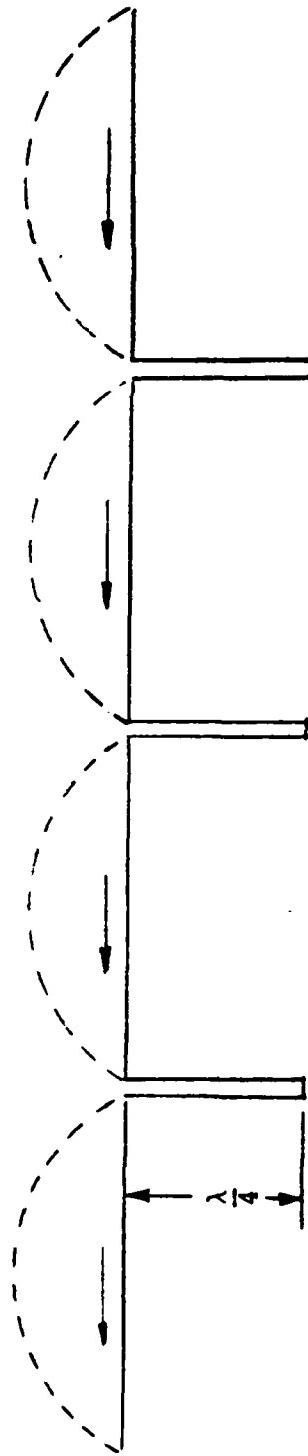


Figure 6-2. INSTANTANEOUS CURRENT DISTRIBUTION OF MODIFIED LONG WIRE ANTENNA

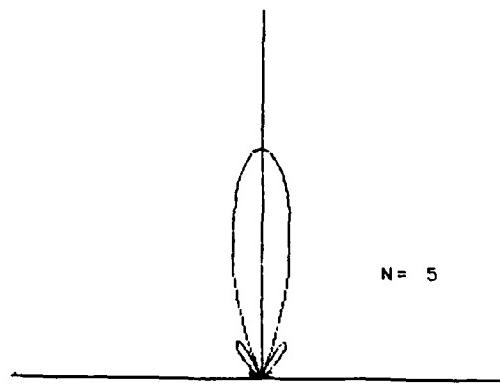


Figure 6-3C. 5 COPHASED DIPOLES

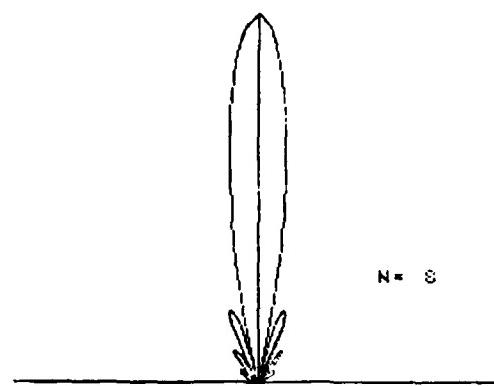


Figure 6-3D. 8 COPHASED DIPOLES

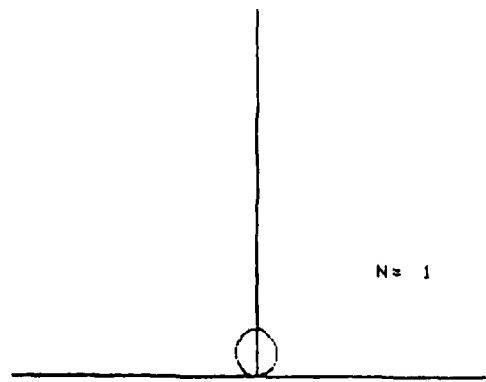


Figure 6-3A. SINGLE DIPOLE

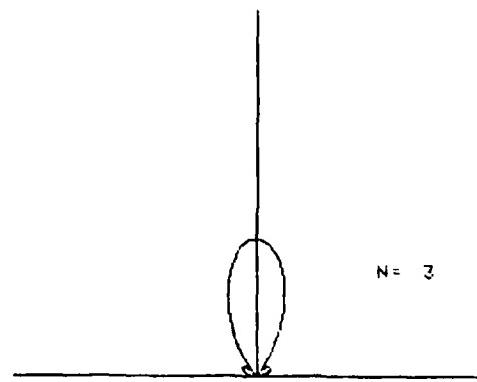


Figure 6-3B. 3 COPHASED DIPOLES

### 6-3 Free Space Patterns for Dipoles in Series



Figure 6-4. Modified Long Wire Antenna & Test Site

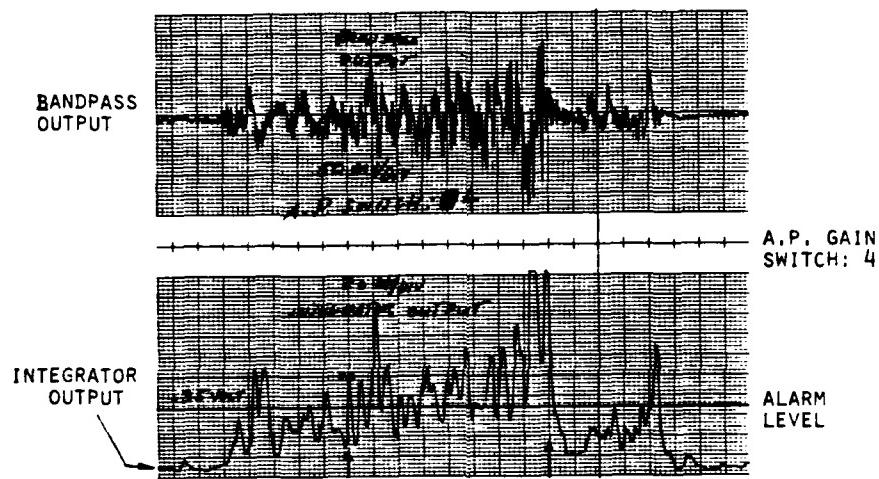


Figure 6-5. MODIFIED TWIN LEAD ANTENNA PARALLEL  
WALK TEST 3 FT OUTBOARD OF CABLE  
(MODIFIED CABLE TRACE IS BETWEEN ARROWS)

## 7.0 CONCLUSIONS AND RECOMMENDATIONS

300 ohms twin lead cable has been shown to give the best overall performance as a confined field transducer. Three configurations of deployment were tested and all three were shown to be effective in confining the surveillance area for a particular resource or application. In summary, the Trolley Wire deployment can provide surveillance for applications such as long corridors or overhead shelf spaces; the Wall Mount deployment can provide surveillance for applications such as shelf spaces and corridors where out-of-reach installation is not mandatory, but good creeper sensitivity is required; the Perimeter Mount can provide surveillance of long but comparatively narrow rooms with more field confinement than spatial antennas. Quiescent noise levels were very low for all three configurations.

It is recommended that supervisory tamper provisions, self-test circuitry, and interfacing provisions be developed along with further study of system optimization for use of RFMS spatial antennas simultaneously with confined field transducers. Transducer configurations for both indoor and outdoor applications should be identified and evaluated for optimal coverage of surveilled area or resources. This would provide more versatility for the RFMS bistatic sensor and increase its range of applications.

## APPENDIX A

### STUDIES ASSOCIATED WITH MECHANICS OF CONNECTORS AND CABLES

Early in the RFMS advanced development program, four types of cable were evaluated for noise under temperature and mechanical stresses. Test fixtures and methods were designed, and tests were performed on cables and connectors to evaluate connector attachment, cable shielding, RF insertion loss, DC resistance, and cable noise under mechanical and temperature stress. The likely cable variations, such as center conductor creepage or noise associated with connectors, produce very small amplitude changes which are difficult to detect. However, phase and VSWR variations associated with these parameters provide a more sensitive indication of these cable changes. The test setup is a high gain quadrature doppler receiver which detects and amplifies these effects. The output of the I and Q channels was sampled 10,000 times over a 10 minute time period for each test to allow for observation of both short term and long term effects. The tests were automated and a Hewlett Packard desktop computer was used for data collection, data reduction, and display of results. The data plots show the sample density for the output of the I and Q channels. Cyclical noise is characterized by peaks in the sample density symmetrically distributed about the zero voltage point. Impulse noise would appear on only one side of the zero volt reference. A block diagram of the test fixture is shown in Figure A-1.

Cable noise under thermal stress was barely discernable and virtually identical for all four of the cables (Belden 9100, RG-213, FSJ1-50, and RG-223). Sample results of calibration to a sine wave input are shown in Figure A-2, and a representative result of the noise test (cable test No. 4) for Belden 9100/UG603A is shown in Figure A-3.

TEST FIXTURE BLOCK DIAGRAM

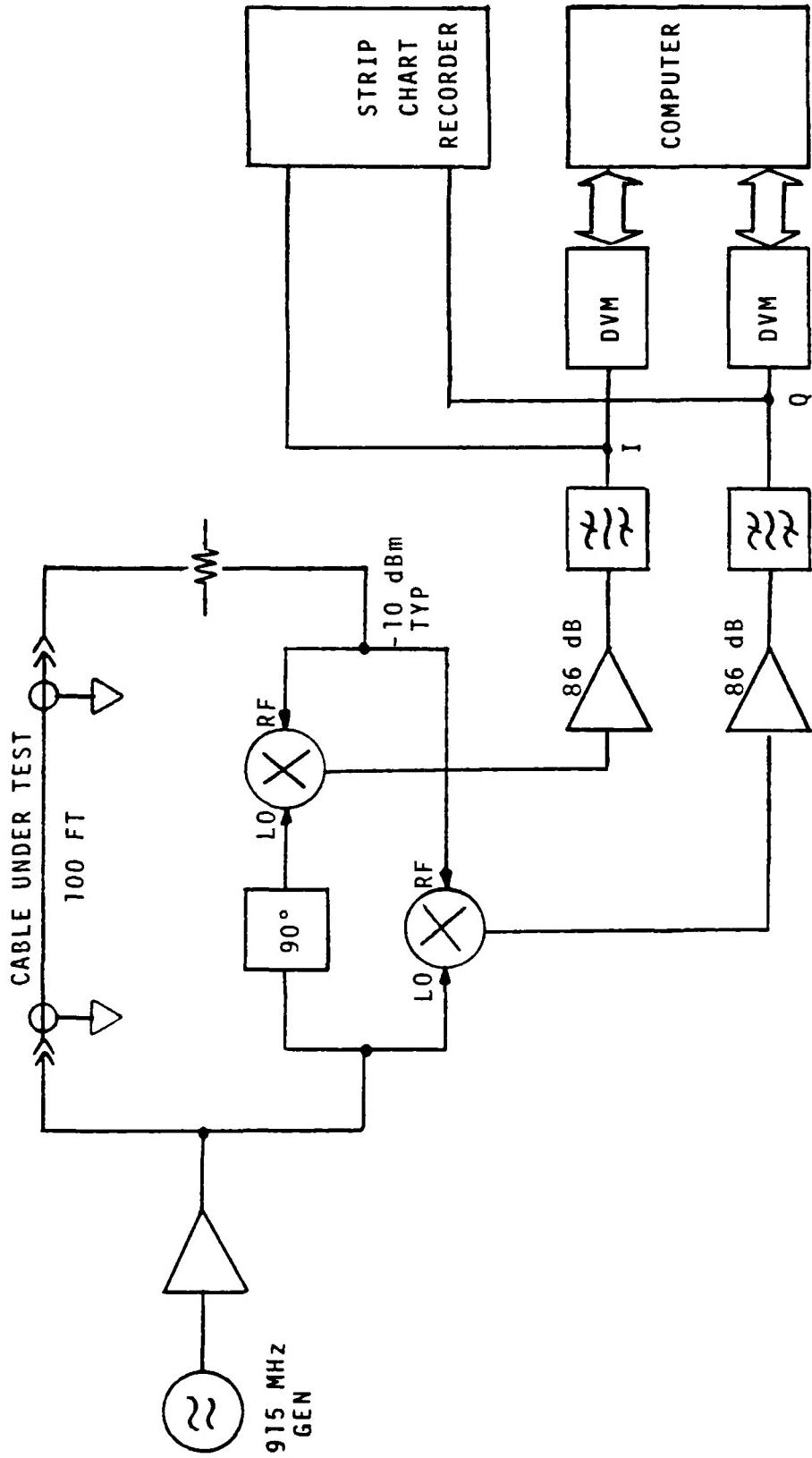


Figure A-1

CABLE TEST

CONNECTOR TYPE:

NONE

TEMPERATURE CYCLE:

NONE

MECHANICAL STRESS:

NONE

DATE:

2 MAY 1981

OPERATOR:

DDW

COMMENTS:

PROGRAM CHECK, SINE WAVE INPUTS

AUTOSTART

MEASUREMENT TIME:

10 MINUTES

1 CHANNEL RESULTS:

MEAN=.009 VOLTS

STD DEV=.59199 VOLTS<sup>2</sup>

NUMBER OF SAMPLES= 10000

0 CHANNEL RESULTS:

MEAN=.015 VOLTS

STD DEV=.389636 VOLTS<sup>2</sup>

NUMBER OF SAMPLES= 10000

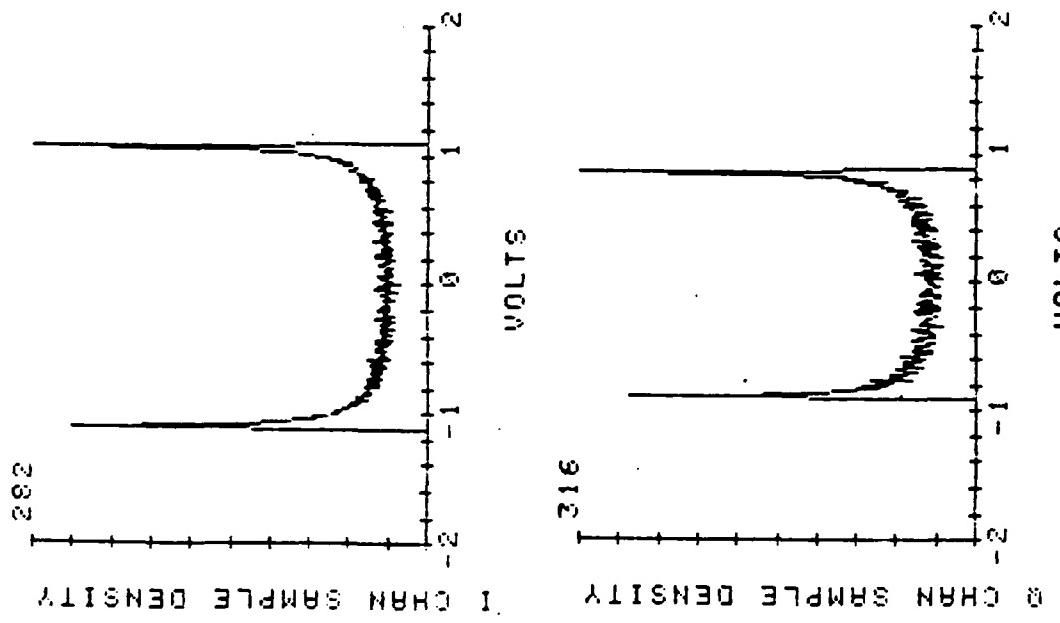


Figure A-2

NOISE TEST, BELDEN 9100/U6603A

CABLE TEST 4

CABLE/CONNECTOR TYPE:  
Belden 9100/U6603A

TEMPERATURE CYCLE:  
NONE ROOM TEMP

MECHANICAL STRESS:  
NONE

DATE:  
5 MAY 1981

OPERATOR:  
DOW

COMMENTS:  
TEST FIXTURE CHECK

MEASUREMENT TIME:  
19 MINUTES

I CHANNEL RESULTS:  
MEAN=-.19 VOLTS  
STD DEV=.015605 VOLTS<sup>2</sup>  
NUMBER OF SAMPLES=10000

Q CHANNEL RESULTS:  
MEAN=-.104 VOLTS  
STD DEV=.028371 VOLTS<sup>2</sup>  
NUMBER OF SAMPLES=10000

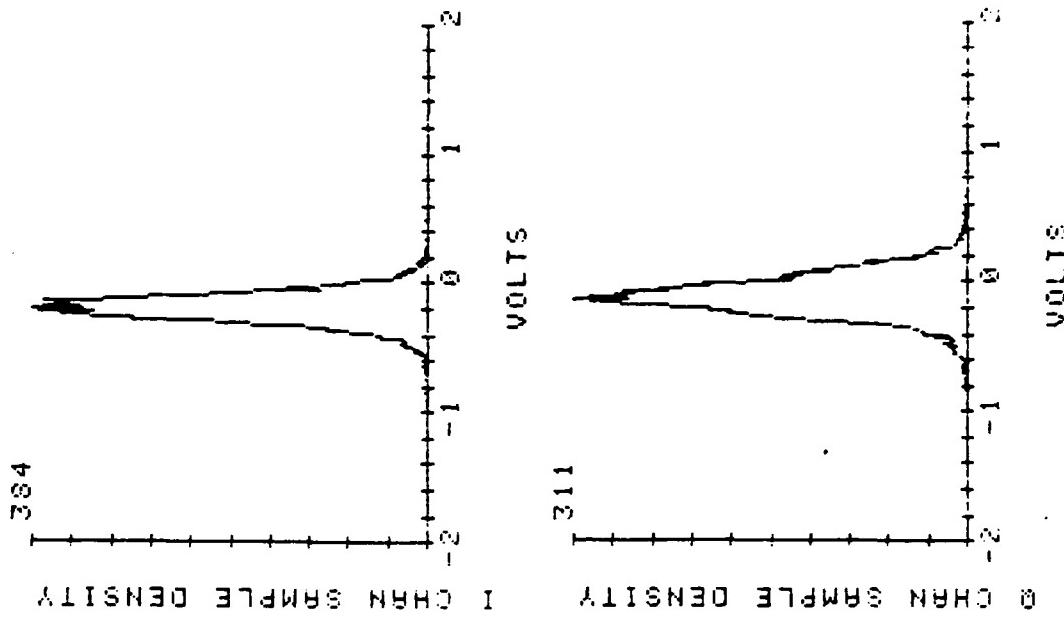


Figure A-3

Belvoir Research and Development Center indicated that a prototype sensor manufactured for them by another vendor had experienced a high false alarm rate which was thought to be associated with cable noise. It is our opinion that VSWR changes due to center conductor creepage under mechanical and temperature stress caused the RF oscillator to change frequency in a small step response manner which was then detected and resulted in a false alarm. Based on this assumption, the test data above, and the Belvoir Research and Development Center information, buffer amplifiers were incorporated on transmitter outputs, including the local oscillator. This design virtually eliminates the possibility of a false alarm from this mechanism.

The cable comparisons are tabulated in Figure A-4. The most important parameter in cable selection for use with the RFMS is DC resistance of the center conductor. DC voltage drop in the local oscillator cable must be limited to less than 2 volts to maintain regulation in the transmitter voltage regulator; otherwise, noisy operation and reduced power output may result. The lowest cost cable consistent with least DC resistance is RG-213 (Belden 8267), and is therefore recommended for use with the RFMS.

### PRELIMINARY CABLE COMPARISON

CABLE TYPE	IMPEDANCE OHMS	RF LOSS dB	DC LOSS 100 METER OHMS	OUTER DIAMETER INCHES	COST \$/100 FT	CONSTRUCTION
RG-59/U BELDEN 9100 (REPLACE 9282)	75	27.6	25.8	0.242	\$10	TWO FOIL SHIELD PLUS BRAID OUTER CONDUCTOR SOLID INNER CONDUCTOR
ANDREWS FSJ1-50	50	22.0	1.8	0.300	\$62	SOLID CORRUGATED OUTER CONDUCTOR SOLID INNER CONDUCTOR
RG-213 (BELDEN 8267)	50	25.6	1.0	0.405	\$43	SINGLE BRAID OUTER CONDUCTOR 97% STRANDED INNER CONDUCTOR
RG-223 (BELDEN 9273)	50	46.9	3.5	0.212	\$125	DUAL BRAID OUTER CONDUCTOR 97% SOLID INNER CONDUCTOR

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